SCIENTIFIC AMERICAN SUPPLEMENT, No. 1878

Entered at the Post Office of New York, N. Y., as Second Class Matter.
Copyright, 1911, by Munn & Co., Inc.
Published weekly by Munn & Co., Inc., at 361 Broadway, New York.
Charles Allen Munn, President, 361 Broadway, New York.
Frederick Converse Beach, Sec'y and Treas., 361 Broadway, New York.

Scientific American, established 1845.
Scientific American Supplement, Vol. LXXII., No. 1878. NEW YORK, DECEMBER 30, 1911. Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

Scene from Country Traversed by the Matterhorn Railway.—[See page 424.]

The Psychology of Light.—III.*

The Subjective Aspect of Optics

By Prof. R. S. Woodworth

Concluded from Supplement No. 1877, page 403.

If, however, a bright light lasts for much longer than its action time, its apparent brightness begins slowly to diminish. The eye becomes adapted to it, and responds less strongly than at first. If a strong light is followed by a weak, the apparent brightness of the latter slowly increases and may finally come to appear much brighter than at first. Brightness depends almost as much on the condition of adaptation of the retina as on the intensity of the stimulus. On passing from bright to dim illumination, the adaptation of the eye proceeds rapidly for the first 1 to 2 minutes, and then more slowly for half an hour or even for several hours. The change in the sensitivity with adaptation is very great, as measured by the least intensity of illumination that can be perceived. The eye is at least several thousand times as sensitive after half an hour in dim light as after half an hour in the sunlight.

The apparent brightness of light is thus affected by the preceding stimulation. It is also affected by the simultaneous stimulation of other parts of the retina; or, in other words, the brightness of any one part of the field is a function not only of the intensity of illumination at that part but also of the illumination at other parts of the field. The main facts belonging here are known under the name of contrast; and contrast might well have been mentioned in discussing color, since the apparent color, as well as brightness, of any part of the field is liable to modification by the influence of other parts of the field. Contrast seems to be an example of the law of polarization or opposition that was spoken of under the head of color theories. If the brightness process is evoked in one part of the retina, this favors the darkness process in other, especially adjacent parts; and if the yellow process is evoked at one part, this favors the blue process at other parts. In general, the calling out of one reaction at one part favors the opposed reaction at other parts in proportion to their proximity. So, a bright light shining into the eyes causes a darkening of any other object which is being examined and interferes noticeably with clear and easy perception. Since contrast is strongest at the junction of the contrasting surfaces, its effect is to accentuate the contours and outlines of objects, and it thus serves an important purpose in vision, since contours are of much value in recognizing objects. Contrast effects are generally overlooked, though all the time they are being utilized for purposes of sharp definition of objects. It is possible to measure contrast effects by comparing the apparent brightness of a surface subjected to the influence of some adjacent brighter or darker surface with the brightness of a control surface free from any strong contrast influence. The illumination of the control surface is varied till it appears equal to that of the surface affected by the contrast, and it is found possible to express the degree of the contrast effect as equivalent to such and such a change in the objective illumination. As thus measured, the brightness contrast is equivalent to a constant fraction of the difference in illumination of the contrasting surfaces. This fraction is constant, in the sense of being independent to the absolute illumination and of the difference of illumination of the contrasting surfaces. It varies with many other conditions, such as proximity. But contrast is, by exception, relatively strong between two surfaces which differ but slightly in illumination; and it is here especially, that the influence of contrast to accentuate contours is of importance. This fact has also been much used in photometry, in which the plan is always to bring the lights to be compared into immediate juxtaposition, without even a line between them, in order that contrast may accentuate any difference between them.

The apparent brightness of a light is thus dependent on a variety of conditions; and one of the most important of these has not yet been mentioned. Brightness depends very largely on the wave-length. This is obvious at once from the fact that the visible spectrum has limits much narrower than the full solar spectrum. The infra-red and ultra-violet rays produce no sensation of brightness, however great their physical energy. At the ends of the visible spectrum, the apparent brightness is low, though the energy of the rays may be considerable, especially at the red end. The brightest part of the spectrum seems ordinarily to lie in the yellow, and this is not simply because the yellow rays contain more energy than the rest, but because the eye is most sensitive to rays of that wave-length. The brightness sense is attuned most closely to a wave-length of about 600 millionths of a millimeter, and less and less closely to rays differing more and more from that on either side. This is true of our ordinary or daylight or light-adapted vision. But in what is called twilight vision, which obtains when the eye is dark-adapted and subjected only to dim light, the brightness curve of a weak solar spectrum differs considerably from that of daylight vision. The maximum is displaced towards the green, and falls at about the wave-length 525; the red end is cut short, the longest waves no longer arousing a sensation, and the short waves have increased in their effect by comparison with the long. At the same time, as has already been mentioned, the spectrum loses its colors and appears simply shaded in gray. The darkening of the red in comparison with the blue is very striking and has long been known under the name of the Purkinje phenomenon. An object which appears of a bright saturated red in the daylight will become black in the twilight, while a blue which appears even less bright by day will still appear distinctly luminous in twilight vison.

The more exact study of the relative brightness of different parts of the spectrum, or in general of different colors, meets with the peculiar difficulties which are recognized by all who have undertaken heterochromic photometry. The pure brightness effect, which one desires to measure, is masked by the color effect. Such comparisons are not altogether impossible, for it is easy to select a brilliant orange which every one would agree to be brighter than a dull blue; or, again a brilliant blue which every one would admit to be brighter than a dull orange. But when finer comparisons are attempted much uncertainty is felt, and some of the most experienced students of the matter have expressed themselves as very sceptical of the validity of such comparisons. Observers differ considerably in equating the brightness of different colors; and the same observer is likely to vary considerably from one determination to another, though he tends, with practice, to settle down to a rather fixed habit, which however need not be right.

On account of this difficulty in the direct comparison of different colors, other methods of heterochromic photometry have been introduced. One is the method of indirect vision. Since the outermost zone of the retina affords no distinction of color, but only of brightness, different colors can be directly equated there, without need of discounting their color. But it is somewhat difficult and annoying to make fine comparisons in indirect vision. Another method is that of the flicker photometer, which has the advantage of giving uniform and rather precise results, although the results are not universally accepted as giving the comparative brightness of the colors. An intermittent stimulus should, apart from the inertia of the sense organ, always give rise to an intermittent sensation, no matter how rapid the rate of intermission. Since an intermittent light gives rise to a steady sensation at 25 to 50 intermissions per second, the eye must be admitted to have a considerable degree of inertia. After each new stimulus, the sensation does not cease abruptly, but dies away only gradually, and the next stimulus gives a new upward shove before the sensation has perceptibly declined from its first maximum; and therefore the sensation is continuous and steady. But if the stimulus is repeated at some greater intervals, the decline from the first maximum before the upward shove of the second stimulus may be sufficient to be noticed; and then an unsteady or flickering sensation results. The greater the inertia of the receiving organ, the less will there be of flicker, and the more readily can it be abolished by increasing the rate of intermission. Again, the less the objective difference between the alternating stimuli, the less will be the flicker and the more quickly may it be abolished by increasing the rate of alteration. Now, probably, all admit the physiological distinction between the brightness and the color sense, even though the psychological effects of the two are so blended as to be hard to disentangle. If the inertia of the color sense should be greater than that of the brightness sense, then flicker due to difference in brightness would persist after flicker due to difference in color had been abolished. This seems to be the fact. For when two colors which differ as much as possible in color tone—namely, two complementary colors, are first equated as nearly as possible in brightness, the flicker between them disappears at a slow rate of alternation in comparison with the rate necessary to abolish flicker between either of them and black.

If the conclusion is justified that flicker due to difference in color is abolished at comparatively low speeds of alternation, then the flicker remaining at higher speeds is due to difference of brightness; and if this in turn is reduced to a minimum by adjusting the brightness of the colors, the inference would be that the colors had now been made equal in their effect on the brightness sense. If one is not disposed to follow this argument implicitly, one might yet agree that flicker would be reduced by anything which made the alternating stimuli more nearly alike; and if altering the intensity of one of the colored lights reduces the flicker to a minimum—since this change has not affected the color—it can hardly have acted otherwise than by equating the brightness effect of the two stimuli.

It appears possible, then, to make out a fairly good case, in theory, for the flicker photometer. But more reliance will probably be placed in a comparison of the results of this method with other methods of heterochromic photometry. A recently introduced method, due to von Kries, and called the minimal field method, is based on the fact that very small spots of color, on a white field, may appear colorless, and, if properly adjusted in brightness, may become indistinguishable from the white background. It was found impracticable to bring the small spot of colored light into foveal vision, the color sense of that region being too acute. But a very few degrees of eccentricity sufficed to destroy the color sensation of the minute spot of colored light, and then its intensity could be adjusted till the spot disappeared. In this way, the relative brightness of different parts of the spectrum was determined, and the curve of brightness so obtained was compared with that obtained by the method of peripheral vision and with that obtained by the flicker method. The comparison (Fig. 1) shows very close agreement between the three methods. The maximum in all three is very close to the wave length of 600, and both slopes of the curve are as nearly coincident as could be expected in view of the errors of observation.

The results of all these methods differ in some important respects from the results of direct comparison of different colors; and some authorities are indisposed to accept any results which are at variance with the immediate appearance. It seems wrong to them to assert that a given red is darker than a given blue, when the direct comparison would lead the observer to assert, often with complete assurance, that the red is the brighter. The question is, however, whether we intend, in heterochromic photometry, to study strictly the brightness sense. The brightness of colors is so blended with their color effect that it

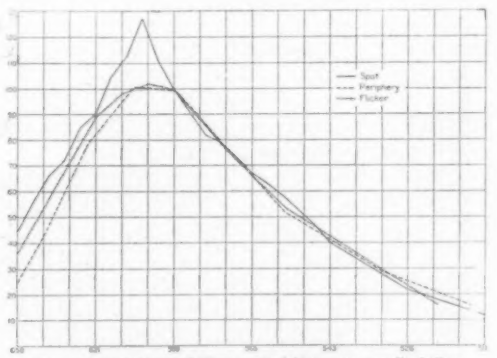


Fig. 1.—Relative brightness of different parts of the spectrum, according to three methods of heterochromic photometry.

is difficult—and there is no guarantee that it is possible—to separate the two by a mere effort of will and attention. Everyone admits that red is the most striking of the colors. It has an impressiveness which is not identical with brighness, but which can not be readily dissociated from brightness. It is probable enough therefore that what the observer is doing in photometry by direct comparison is to compare the total effect or impressiveness of two colored lights, rather than their brightness in the strict sense. Whether this total impressiveness of a light is not what needs to be measured for many practical purposes is another problem to be worked out by still other methods.

* Reprinted from the Transactions of the Illuminating Engineering Society.

No complete agreement can be expended between the results of different observers, by whatever method they attempt to compare the brightness of different colors. What is measured, in all photometry, is of course a subjective and not an objective phenomenon; it is the response of the eye and brain to light, and not the physical energy. There is no objective fact corresponding precisely to brightness or luminosity. The individual differences which appear are therefore not simply errors of observation, but indicate that the response to light differs in different eyes. This is especially the case in regard to the relative response to different rays. In that sub-class of the color-blind called red-blind or protanopic, there is very low sensitivity to the red end of the spectrum, so that a brightness equation between red and green would come out very differently with a red-blind observer than with the average observer. But it would be far from correct simply to set off red-blind individuals as a special class, and regard all others as alike. For even among individuals who have, according to all the tests, strictly normal color vision, there is a wide variation in the relative sensitivity to red and to green. Normal individuals vary in this respect at least in the ratio 2 to 1, and apparently, in exceptional cases, as much as 8 to 1. That is to say that one normal eye has been found to be as much as eight times as sensitive to red as another, in comparison with the sensitivity to green. This comparison was made by the flicker method, other methods also showing somewhat similar differences.

Individual differences constitute a subject of much psychological interest, and perhaps the psychologist is more alive to the fact of such differences than the physicist or students of other sciences. Whatever function the psychologist tests, he has always found differences between individuals. These differences are in almost all instances to be regarded as differences in degree, and not as differences in kind. Differences in kind often result from the action of disease or injury; and differences which are practically differences in kind arise from special training, as, for example, mankind can very easily be divided into those who can telegraph and those who can not, though there might be a few doubtful cases. Such sharp divisions of mankind in mental functions are seldom if ever found as the result of native differences. The case of color-blindness seems an exception to this rule, since each individual seems to be born with either dichromatic or polychromatic, or, very rarely, with achromatic vision. If mankind is really divisible here into three types or species as regards their color sense, the reason is that vision is really a compound of at least three senses, the brightness sense of the rods, and the yellow-blue and red-green senses of the cones. There is also, probably, a brightness sense of the cones, but a total color-blindness with integrity of the cone brightness sense is, so far as the author knows, not demonstrated. However this may be, it would seem that the line between the normal and the red-green blind individuals is not perfectly sharp; it seems to be bridged over, to a degree, by individuals classed as color weak, who may be regarded as possessing a red-green sense, but one of subnormal efficiency. Moreover, it is certain that individuals who are classed as strictly normal are yet not all alike in color sense. They show minor differences, some being less sensitive to red than others, some having the point of maximum brightness in the spectrum a little farther towards the green than others, some finding somewhat different pairs of rays complementary from others. All these differences can be readily understood in terms of color theory if it be supposed that the sensitivity of the several photochromatic substances differs slightly from one individual to another, and that the attunement of each substance to a specific wave-length is also capable of variation.

The most important bearing of the facts summarized in the color pyramid is in relation to theories of retinal action. Though the facts are strictly psychological, their interest is mostly physiological. Most of the psychological interest is in the utilization of light for purposes of perception. From the point of view of utility, or from the point of view of mental life in general, the important thing is not the mere occurrence of a sensation of such and such brightness, color and saturation, but the perception of objects and of their qualities and conditions. The perception of objects depends very largely on the ability to observe differences within the field of view. The differences of color or brightness serve as indications of the outlines and molding of objects. One of the most elementary acts of perception is the noting of a difference of brightness; and the study of such perceptions has been one of the great concerns of the psychologist. How small a difference of brightness can be observed? The answer to this question is by no means simple. In the first place, much depends on the manner in which the lights to be compared are presented to the eye. If first one stimulus is presented, and then, after an interval of a second or two, another, the two must differ considerably in intensity in order that their difference may be perceptible. A smaller difference can be detected if both stimuli are presented simultaneously in different parts of the field of view. But the smallest difference can be perceived when the two stimuli are not only present together in the field, but when one immediately adjoins the other, without so much as a line of demarcation. Even under these conditions, however, it is impossible to give a simple expression of the power of discrimination. One can not state that a difference of a certain number of meter-candles is the minimum perceptible; for the least perceptible difference varies with the absolute intensity of the stimuli. A difference of a small fraction of a meter-candle can be observed when the two adjoining surfaces have each an illumination of less than a candle-meter, where a difference of a thousand meter-candles will pass unobserved when the surfaces are very brilliantly illuminated. So familiar is this fact that no one thinks of expressing the least noticeable difference in absolute units; instead, the usual expression is to the effect that the eye can distinguish a difference of brightness when one surface is one one-hundredth more intensely illuminated than the other. The fraction varies with the individual and his training, as well as with the conditions of the observation; sometimes it may be as small as 1/200; but often considerably larger than 1/100. In so far as any such constant fraction can properly be used as an expression of the power of discrimination, the famous law of Weber is substantiated. Weber's law states that the least noticeable difference, for any given sort and conditions of discrimination, is a constant fraction of the total stimulus. If Weber's law were unqualifiedly true, the task of the illuminating engineer would be limited to the consideration of questions of the color of light, since intensity would be a matter of indifference for purposes of perception. For if one of two surfaces reflects 10 per cent more light than another under one illumination, so it does under any other illumination; and the differences would, according to Weber's law, be equally perceptible under all illuminations. As a matter of fact, Weber's law does not hold good at very faint or very intense illumination; in both cases a larger fractional difference between the stimuli is necessary for it to be perceived.

The most thorough test of Weber's law in intensity of light is afforded by the experiments of König and Brodhun, who operated with a great range of intensities, obtaining results as shown in the following table.

König and Brodhun's arbitrary units	Meter-candles (approximate)	Least perceptible difference
0.5	0.9	1/3.9
1	1.8	1/5.7
2	3.6	1/8.3
5	8.9	1/14.4
10	17.8	1/21
20	35.6	1/27
50	89	1/33
100	178	1/40
200	356	1/45
500	890	1/51
1,000	1,780	1/57
2,000	3,560	1/59
5,000	8,900	1/61
10,000	17,800	1/60
20,000	35,600	1/57
50,000	89,000	1/47
100,000	178,000	1/34
200,000	356,000	1/26

The fraction in the last column of this table show the least noticeable difference in intensity in relation to the total illumination. According to Weber's law, this fraction should be independent of the absolute illumination. When the whole range of intensities is taken into account, this is seen to be far from the truth: the fraction is large at small intensities, decreases steadily with an increase of intensity, then remains almost unchanged for a considerable range of medium illuminations, and finally increases again at very high intensities. In strictness, indeed, the fraction seems scarcely to remain constant at all, but rather to decrease at first rapidly and then slowly to a minimum, beyond which it at first slowly and then more rapidly increases again. If it be admitted that the important thing in perception is rather the noting of a relative than of an absolute difference—since it is the relative difference which remains objectively unchanged under variations of illumination, and which therefore gives valid information regarding objects themselves, rather than regarding the light which chances to fall upon them—then may one consider perception as equally good wherever the fraction is equally small; and where the fraction is at its minimum one may properly speak of perception as being at its maximum or optimum. Thus the denominator of the fraction may be used as a measure of the goodness of perception, and a picture of the goodness of perception as dependent on illumination may be obtained by simply plotting the curve of the denominator. The curve would be unwieldy to plot on account of the great range of intensities, but inspection of the table shows that it would rise with increasing illumination, at first rapidly and then slowly, remaining nearly level for a considerable range of medium intensities and then slowly sinking again. The nearly level portion is that where Weber's law is approximately true; and, from our present point of view, this law, with its limitations, seems simply a statement of the fact that there is an optimum illumination for observing differences, but that this optimum is in the midst of a nearly level part of the curve. The facts in the perception of sound, weight, etc., admit of a similar formulation.

As to the illumination which gives the optimum perception, the results of König and Brodhun would assign about 10,000 meter-candles as the summit of the curve, with approximate equality from below 2,000 to about 35,000 meter-candles. But this holds good only for the special conditions of these experiments, in which the illuminated field was small and was viewed through a small aperture. Since the optimum illumination would undoubtedly depend not only on the intensity of the light but also on the total quantity entering the eye, it is probable that, under ordinary conditions of vision, the optimum would be reached at a lower illumination.

Another favorite study of the psychologist is the speed of reaction to various stimuli. It is a curious fact that, in spite of the high development and importance of the sense of vision, the reaction to light is slower than to sound or touch. There is some element of slowness in the simplest reaction to light. The quickest response by a hand movement to the reception of light, when nothing need be attended to except barely to move the hand as soon as the light is seen, is about 0.160 sec.; while the quickest reaction to sound is usually below 0.150 and may sink to 0.120 or even to 0.100. Individuals differ considerably in their absolute times of reaction, but agree in the relative slowness of the reaction to light. Explanation of this fact is not yet agreed upon, and several possibilities remain open. It may be that the photochemical process of retinal excitation is slower than the mechanical process that takes place in the ear or skin; or it may be that the nervous pathways leading in from the eye are less simple and direct than those from the ear and skin; or it may be that the nerves from the ear and skin have better central connections with the motor nerves.

The reaction time is inversely related to the intensity of the stimulus. Increasing the intensity of the light causes the reaction time to decrease, as the following results show:

Intensity in arbitrary units	Reaction time seconds
100	0.191
56	0.194
25	0.197
16	0.202
10	0.208
7	0.210
3	0.215
2	0.220
0.8	0.226

The lowest of these intensities is that of light reflected from "black" paper, and is still distinctly above the threshold; and the reaction time might be expected to rise to about 0.300 sec. just above the threshold. The differences in the above-quoted reaction time are certainly small; and they are so masked by accidental variations that only a long series of trials, with well-trained reagents, could give results as regular as the above. Even slight differences of speed are however sometimes of moment; and the results with the simple reaction may probably be taken as indicating that any process depending on vision gets started more quickly when the light is at least moderately intense than when it is feeble.

Increasing the area of the light surface causes a quicker reaction, as well as increasing the illumination; and, within the limits of the "action time," increasing the duration also quickens the reaction.

Many questions, regarding the effect of different lights on perception, reaction and emotional tone are of practical as well as scientific interest; and it is likely that in the future the psychologist will look to the illuminating engineer for data on these problems, fully as much as the engineer will look to the psychologist.

Photographs on Writing Paper

To transfer photographs to writing paper, proceed as follows: Select thick paper and cover the same with a thin paste of rice starch, to which has been added some dye stuff. Allow to dry completely and then apply a solution of 3 grams potassium bichromate in 50 cubic centimeters of water. This must be done in the dark room, using a red light; the paper must be left there until dry, when it is ready for use. Develop in water, which will remove superfluous starch-paste from the unexposed parts.—*Drogisten Woche.*

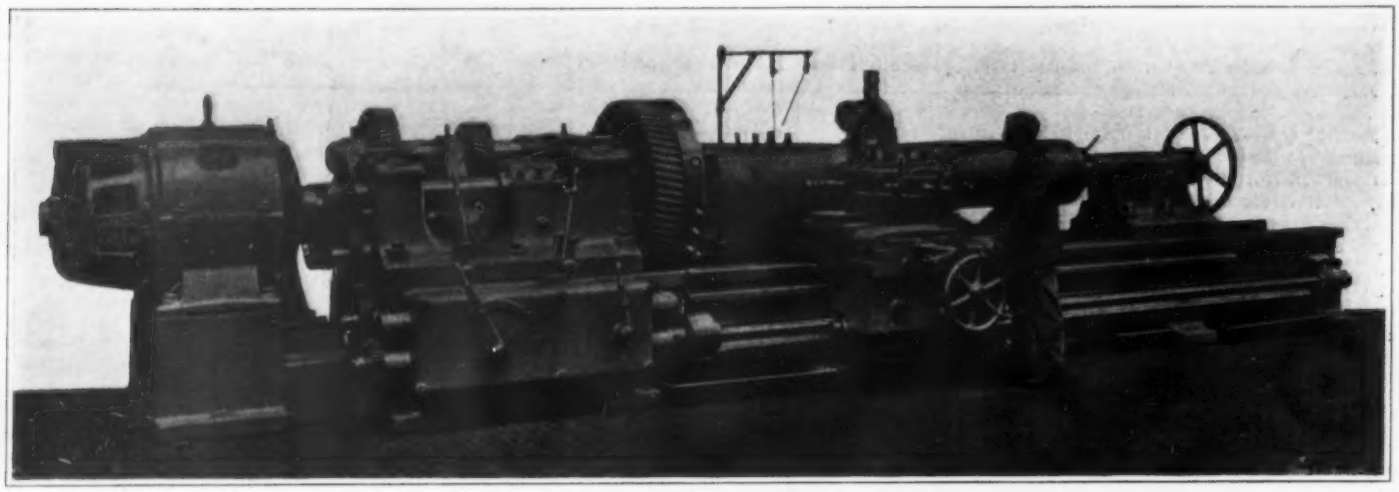


Fig. 1—Lathe and Dynamometer Set for Turning Tests.

A Lathe for Testing Tools and Drills

Built for the Japanese Navy

THERE has recently been built at the Openshaw Works of Sir W. G. Armstrong, Whitworth & Co., Limited, a powerful 18-inch center high-speed lathe for the Japanese navy. It has been specially constructed, says *The Engineer*, for carrying out tests on tool steel, as well as for doing general work. With the former object it is provided with Dr. Nicolson's tool dynamometer for recording the vertical, traversing and outward forces for cuts up to 0.08 square inch area, and for testing the torque and thrust of twist drills up to 3 inches in diameter. A general view of the lathe and dynamometer set for turning tests is given in Fig. 1, while Fig. 3 shows the lathe adapted for drill tests, and Fig. 2 shows the arrangement of the drill dynamometer in elevation and plan. The lathe will take in work 13 feet long between the centers, and is driven by a 60 horse-power variable-speed motor. This, together with the gear changes, will give a range of face-plate speeds between 3½ and 62 revolutions per minute. To insure smooth motion the headstock gearing is of the single helical pattern, and the various gears are engaged and disengaged by means of the two levers shown in front of the headstock. The spindle of the fixed head is made of fluid pressed forged steel, and runs in parallel phosphor bronze bearings, the end thrust due to cutting being taken by a ball bearing behind the front bearing of the headstock. The sliding feeds are six in number, giving from two to sixteen cuts per inch, the changes being obtained by the two levers on the gear-box in front of the bed.

In order to permit of specially fine feeds for drilling tests to be obtained, special gearing is arranged at the end of the bed. These feeds range between twenty and one hundred cuts per inch. The feed shaft in front of the bed is driven by a slipping clutch, the tension of which can be adjusted to the desired degree. The saddle is fitted with two top rests, one on the front and the other on the back, and is propelled along the bed by means of two steel pinions meshing into steel racks, one on the front and the other at the back of the lathe. The saddle is also provided with mechanism for starting, stopping, and reversing the feeds. The mechanism is controlled by means of levers placed in a convenient position for the workman. A hand traversing arrangement is also provided.

The loose headstock is of heavy design, and is clamped to the bed by six bolts. All gearing is machine cut from solid blanks, the face plate gear wheel being of forged steel, and the remaining headstock wheels of steel or brass. The feed wheels, too, are all either forged steel or brass, and all wheels are provided with guards—not shown in the illustrations. The dynamometers are of Dr. Nicolson's design, and were made by Messrs. Joseph Adamson & Co., Hyde. The object of these appliances is to ascertain the pressures operating between the work and the cutting tool, as affected by the material, the size and shape of the cut, the speed of cutting, and the form of the tool point. The principles on which the appliance is based were described by the inventor before the Institution of Mechanical Engineers in 1905. The design has, however, been materially improved, so that a vertical force of seven tons on the point of the tool can be withstood. A modification of some importance, too, has been introduced in the drilling attachment shown in Figs. 2 and 3, which is calculated to render it more sensitive and also capable of use with the largest drills or boring tools. In the original design the apparatus was secured to one slide rest only, and it was difficult to avoid springing of the rest due to the backward push of a large drill. In the present appliance this is avoided by the provision of the special casting *A* to

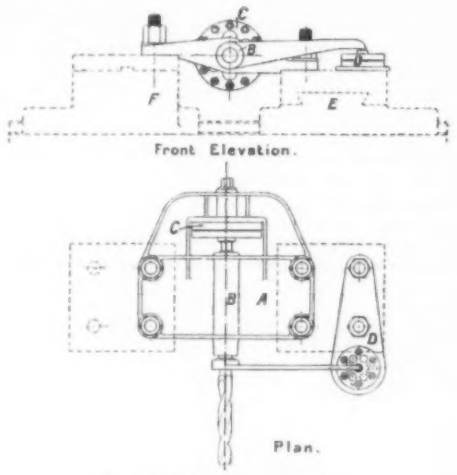


Fig. 2—Drill Dynamometer.

Fig. 3—Lathe Arranged for Drill Testing.

bridge over both the front and the back rests *E F*. The drill is guided without friction in the tubular portion *B* in this casting, and is kept central with the lathe axis. Two of the dynamometer diaphragms *C D* from the lathe tool appliance are fitted on the casting—one, *C*, to measure the feed force, and the other *D*, the torque. The dynamometer is strongly built, the castings being of steel throughout.

The Tatin-Paulhan "Aero-Torpedo."

THE French pilot Gaudart has been experimenting during the past few months with an aeroplane which seems entirely new in conception, but which is, however, built on a model recommended by Victor Tatin more than twenty years ago.

The ideas then advanced by Tatin and defended with such skill and strength of argument in numerous articles and brochures and in the two books, "Elements of Aviation" and "Theory and Practice of Aviation," attracted the attention of Louis Paulhan. Though engaged in building biplanes and triplanes of entirely different design, he resolved to make the attempt to realize Tatin's idea of a machine of high speed and small fuel consumption, which accounts for the genesis of the well-named Tatin-Paulhan "aero-torpedo."

The shape of this machine is designed with a view of offering as little resistance to the air as possible; to use Tatin's words, to make "a good projectile," and to obtain as high a speed as possible with relatively small power.

The principal dimensions are:

Spread of wings, 8.60 meters (28.2 feet).

Length of body, 8.60 meters (28.2 feet).

Supporting surface, 12.5 square meters (134.55 square feet).

Weight, empty, 360 kilograms (793.66 pounds).

Gnome motor, 50 horse-power.

The propeller is placed at the extreme rear end of the body, entirely outside. The wings, nearly flat, are curved at the edges in such manner that, seen from the front, they present the form of a semi-ellipse cut off a little below its greatest diameter. Their maximum thickness is 10 centimeters (3.94 inches). Their horizontal projection is an ellipse whose two ends have been clipped off to facilitate construction. Each wing has a spread of 3.85 meters (12.63 feet) and a width of 2 meters (6.56 feet) at the fuselage. They are slightly warpable.

The spindle-shaped body is composed of cloth stretched on a framework of circular supports; the forward part has the form of an ellipse of revolution, while the rear is a slightly bulging cone. The wings are fastened to the fuselage, at about the second quarter of its length, beginning at the front. They are held in place by the guys, the upper of which run to a single small mast, while the lower are attached directly to the bottom of the fuselage.

At the rear of this fuselage is fixed the tail, which is flat. Its horizontal projection is identical with that of the wings. The rear part of the tail is movable and performs the office of a horizontal rudder. The vertical rudder is mounted on top of the body, at rear.

The chassis for landing is composed of two curved pieces of wood, extending in the direction of the longitudinal axis of the machine and fastened to the fuselage at their front ends. The rear extremities of these curved pieces are united by a wooden bar which is fastened by shock absorbers to a beam affixed to the fuselage.

The motor is a 50 horse-power Gnome, which is placed in the fuselage at the location of the front of the wings. It drives the propeller at the rear end of the body through a universally jointed shaft running in five bearings supported in the fuselage by piano wire.

Predictions.—M. Tatin, in his studies of this apparatus, predicted a speed of 125 to 130 kilometers (77.67 to 80.77 miles) per hour, with a propeller of 2.10 meters (6.86 feet) pitch, an expenditure of 22 horse-power, an angle of flight of 3 degrees, and a weight of 450 kilogrammes (992 pounds).

For the same weight, but with a propeller of 2.50 meters (7.2 feet) pitch, an angle of 2 degrees, and an expenditure of 33 horse-power, he predicted a minimum of 150 kilometers (93.2 miles) per hour.

With an effective power of 40 horse-power, a speed in excess of 160 kilometers (99.4 miles) per hour would be attained. With a propeller of 2.10 meters pitch, all the predictions of Tatin have been realized, which argues well for the others.—*Aerophile.*

A New Theory of the Cause of Rail Corrugation*

The Effect is Ascribed to the Pressure on the Rail Locally Exceeding the Elastic Limit

By G. E. Pellissier, Superintendent Goldschmidt Thermit Company

THE writer first became interested in the subject of rail corrugation when acting in the capacity of engineer maintenance of way for an electric-railway company, and since that time he has had an opportunity to inspect a great deal of corrugated rail in many cities of the United States and Europe. His study of the question has been directed to an effort to find an explanation of this phenomenon which would not only fulfill the conditions of possibility but also those of probability.

In considering the various theories which have already been advanced as to the cause of corrugation one must necessarily be impressed with the fact that while all of the causes mentioned might be responsible for corrugations under certain particular conditions, they fail to fulfill the requirements of probability, because these causes, while continually operative, are assumed to produce corrugations only where they happen to appear, whether it is in the middle of a straight rail or on a curve, while on the remainder and greater portion of the track they have no effect. In some cases the rail not affected is less than 5 feet distant from the one that is.

For instance, taking only one of the theories advanced, it hardly seems probable that dust or grit blown upon the track could be responsible for corrugations as found, since the chance of this dust being continually deposited on one rail and not on the other rail, only 5 feet away, or in places in the track 50 feet or 100 feet apart, is very small.

The same argument might be applied to other theories which attribute all corrugations to chattering of the rolls when the rails are rolled, to vibration, hard spots in the rail, elongation of the fibers, due to the rolling action of the wheels, etc., as they in no way account for the fact that the corrugations appear only on widely distributed parts of a system of tracks, while the causes mentioned are operative over the entire system.

Approaching the question, therefore, from the point of probability the writer came to the conclusion that the corrugations themselves must be due to certain definite causes, which in turn might be the result of one or several conditions; that these conditions of necessity had to be operative where the corrugations occurred and not operative where they did not occur, and that there must be a reason for the change of conditions.

Proceeding on this assumption, the conditions under which corrugations appear were investigated and the following significant facts noted:

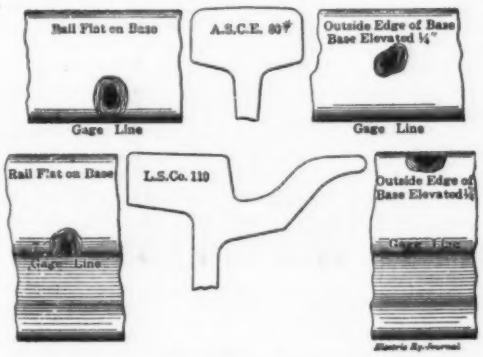
Corrugations rarely appear on steam roads, and rarely, if ever, on interurban track laid with T-rail, except at or near stations or under abnormal conditions; that T-rail in paved streets is not much affected; that high girder rail in paved streets is most susceptible to corrugation; that corrugations are often found on the outside rail of long radius curves, but rarely, if ever, on very short radius curves provided with a guard rail; that corrugations are more apt to appear where the rail is laid on a solid foundation with solid paving against the side of the rail; that rails which corrugate in one location sometimes wear smooth if taken out and laid elsewhere; that corrugations sometimes occur in parts of one rail and not in the remainder of the same rail.

In addition to the above facts, which it is believed are generally accepted, the writer has seen evidences of corrugations in less than forty-eight hours after a track was lain under conditions which will be noted.

Any explanation of the phenomena of corrugation which is advanced must necessarily account for the facts above mentioned in order to be satisfactory. The writer has evolved the following theory, which it is believed fulfills these conditions:

That corrugations are directly due to non-uniformity of pressure between the tread of the carwheel and the surface of the rail, and between the flange of the wheel and the side of the rail head, and they occur only when the pressure at the point of maximum intensity of pressure exceeds the elastic limit of steel at that point; that any condition or set of conditions which produce this non-uniformity of pressure will cause corrugations if the maximum intensity of pressure exceeds the elastic limit of the rail material; that comparatively few combinations of circumstances cause the maximum intensity of pressure to exceed the cubical elastic limit of steel; that any conditions which cause the position of a point of maximum intensity of pressure to move away from the approximate center of the rail head to the edge where any particles are not restrained, but free to move in one or more directions, reduce the elastic limit to its linear value, which is not more than one-third of its cubical value, according to good authorities; that the shape of the rail head, wheel tread and wheel flange, and the position of the one relative to the other under traffic, has great influence on the position of the point of maximum intensity of pressure, and thus is responsible for most of the corrugations; that by so designing the rail head, wheel tread and wheel flange and so laying the rails that the maximum intensity of pressure will occur near the center of the tread surface of the rail and as far as possible from the corner or edge of the side of rail, most of the corrugations can be eliminated; that corrugations produced by pressures exceeding the cubical elastic limit of steel (such as might occur with quick braking of heavy, fast trains) can be eliminated only by raising the elastic limit of the steel, increasing the area of contact between the wheel and rail, or by making the acceleration (positive or negative) so uniform that a uniform cold flowing of the metal will follow.

In support of this theory a few facts regarding the intensity of pressure and its point of application may be of interest. Considering the surface of the rail a horizontal plane and the wheel a right cylinder, the contact between the two would take place along a straight line, neglecting for the moment elasticity. If, however, the surface of the rail is a plane and the wheel is conical, the contact between the two occurs at a point, unless the wheel or the rail are free to move until an element of the cone coincides with an element of the plane. Since, however, in the case of rails laid in pavement it is not possible to obtain this adjustment of wheel and rail, and because we not only have coned wheels, but rails whose heads are not plane surfaces, we obtain contacts between the two varying from a point to a line, modified by the elasticity of the metal to a spot and an irregular area across the head of the rail.



Figs. 1 and 2—Contact Areas on Girder and T-Rail.

Actual measurements of the area of contact made on various types of rails by placing a pair of standard 20-inch wheels fixed on an axle and then applying a pressure of 5 tons to each wheel showed the area of contact to vary from less than 0.25 square inch to about 0.75 square inch, depending on the type of rail and its position relative to the wheel.

The accompanying sketches, Figs. 1 and 2, show roughly the relative size and location of a contact area. These, of course, are only representative and would be modified when the car was in motion and when the load and diameter of wheels were varied.

As the wheel load of 5 tons is not excessive, since in practice 6 tons or 7 tons are not uncommon, the areas found by experiment may be used to calculate the unit pressure on the rail. Assuming the intensity of pressure to be uniform over the entire area of contact, where the area of contact was 0.25 square inch the intensity of pressure would be 40,000 pounds per square inch, which is certainly close to, if it does not exceed, the linear elastic limit of ordinary rail steel.

When we consider, however, that the intensity of pressure is not uniform, but varies from nothing at the edge of the contact area to the maximum at the center, and that these figures are materially increased by loading, impact, breaking, etc., it is readily seen that the linear elastic limit of steel must often be exceeded. It must not be forgotten also that in producing these contact areas new wheels and rails were used, that care was taken to place them so that the maximum area of contact would be developed, and that the rails were merely laid on a cast iron bed plate, so that they were free to adjust themselves under pressure.

With rails as laid in track and subjected to traffic we find quite a different set of conditions. The rails are held together by tie rods or supported by rail braces and are embedded in pavement so that they are not entirely free to adjust themselves under pressure. The position of the point of maximum intensity of pressure, therefore, is determined largely by the shape of the wheel and rail. Secondly, the track is rarely laid so that the wheels will make contact with the rail at corresponding points along its entire length. Thirdly, on account of defective gage of track and wheels the contact cannot always take place between the tread of the wheel and the surface of the rail, but somewhere along the gage line. Fourthly, flanges sometimes ride either on the bottom of the groove or on the inside of the groove. Fifthly, centrifugal forces tend to make the wheels climb outside the rail when going around curves. Other differences could be noted, but the above are the most important.

It will readily be seen from the sketches shown in Fig. 3 that in all the cases illustrated the area of contact must be materially reduced. If the rails were free to adjust themselves under pressure all the other conditions mentioned would be of small moment, as the point of maximum intensity would tend automatically to keep away from the edge of the rail, both on the tread and side of head. When, however, the rail is not free to adjust itself the rail head and wheel tread must be so shaped that under traffic conditions the point of maximum intensity of pressure will not fall at the edge of the rail. This, of course, can be accomplished in many ways, but the simplest way which naturally presents itself is to make the tread of the rail approach the arc of a circle instead of a plane, as most girder rails are rolled. The radius of the curves at the gage lines should also be such as to bring the flange pressure under traffic conditions well below the edge of the rail, as illustrated in Fig. 5.

Analyzing the occurrence and non-occurence of corrugation on the basis of this theory, it is not difficult to see why corrugation rarely occurs on steam

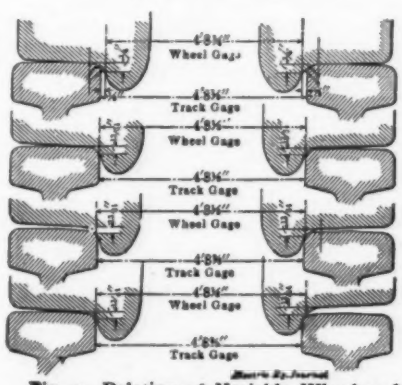
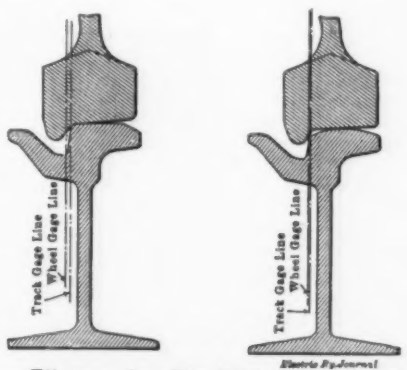


Fig. 3—Relation of Variable Wheel and Track Gages



Figs. 4 and 5—Flat Head and Proposed Rounded Head Girder Rail

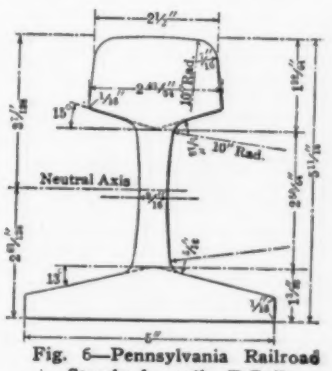


Fig. 6—Pennsylvania Railroad Standard 100-lb. T-Rail

* Reproduced from the *Electric Railway Journal*.

roads, as not only is the rail free to adjust itself so that the point of maximum intensity of pressure falls near the center of the head, but the shape of the head is such as to obtain this result even though the rail was not free to move. Fig. 6 shows rounded-head rails used by the Pennsylvania Railroad. In exceptional cases where slight evidences of corrugation have been found in steam roads, in yards or near stations, the cubical elastic limit of the steel of the rail undoubtedly has been exceeded, due to the combination of wheel loads and tractive forces exerted in starting and stopping trains, and as the positive or negative acceleration is not uniform the result is a non-uniformity of pressure. On some curves where there is no doubt that the cubical elastic limit of steel has been passed, but where there is no necessity for stopping and starting, a uniform cold flowing of the metal of the steel of the rail will be found. The same argument holds, of course, for interurban track.

With nearly all T-rails laid in paved streets the shape of the rail head tends to keep the point of maximum intensity of pressure near the center, but as the rail is not free to move all the cases illustrated in Fig. 3, except the top one, can produce corrugation. In the case of outside rails on long radius curves the wheel flange presses against the side of the rail with a pressure varying with the speed. When the rail is not properly shaped the tendency is for the wheel to climb the rail, lifting the tread of the wheel from the rail surface and bringing the maximum intensity of pressure at the very edge of the rail. As soon as this pressure exceeds the linear elastic limit deformations occur and the wheel drops until the area of contact is sufficient to reduce the pressure below the elastic limit, when the wheel again starts to climb. As the time required for the wheel to drop a certain distance is constant and the speed of the cars varies, it will readily be seen that the length of the corrugations thus produced will be a function of the speed of the cars.

Quite a different effect is obtained on short radius curves. The speed is not sufficient to cause climbing due to flange pressure, and as the inside of the flange makes contact with the guard the area of contact is certain to keep the maximum intensity of pressure below the elastic limit, even if the point of maximum intensity falls near the edge, which it does not, as shown by the wear on the guard rail.

This theory further explains why in some cases grinding removes corrugations and why in other cases it does not. If the grinding simply removes the inequalities of the rail surface without changing the relation of wheel tread and rail surface, corrugations will again appear, while if the grinding does change this relation, taking the center of pressure away from the edge of the rail, corrugations will not occur. The occurence of corrugation under various other conditions could be explained by this theory, but the above will be sufficient, it is believed, to demonstrate its soundness.

It is the intention of the writer to make some experiments with a view of determining the actual intensity of pressure between wheel and rail with various types of wheels and rails under different conditions as soon as opportunity offers.

The Physiological Aspect of Ventilation*

The Part Played by Imagination in Producing Discomfort in a Stuffy Room

By Theodore Hough, University of Virginia

IT IS an old story, that of the man who was unable to go to sleep in a strange hotel because he could not open the window before retiring; finally, in sheer desperation, he threw his iron boot-jack against the glass and broke it; after which he fell into a profound slumber which was undisturbed until daylight awoke him and revealed the fact that he had only broken the mirror which formed the door of his wardrobe.

I cannot say that this incident ever happened, but I have no doubt that the story truly illustrates one phase of the physiology of ventilation, namely, the large rule which the psychic factor plays in it. If one knows that the air is bad or believes that the room is close, physiological results often follow which would not otherwise occur.

My own very limited laboratory experience with the subject under discussion furnishes another striking illustration of the same thing. Some years ago I was interested in a research which involved shutting the subject of the experiment for an hour or more in an airtight box approximately 3 x 5 x 7 feet, thereby subjecting him to the effects of respired air. The percentage of CO_2 rose to 50 or more parts in 10,000. When the observer opened the door the odor of the air within was almost overpowering; and yet, provided the water vapor was absorbed and the temperature of the box kept down, the subject of the experiment had not only been unconscious of this odor but had actually suffered no discomfort. It can hardly be doubted that if he had been conscious of it, he would not only have been very uncomfortable but could not have done the mental work which, as it was, he performed easily in many of the experiments. The substances producing the odor had accumulated so gradually and been so evenly distributed throughout the closed space that there was no adequate stimulus to the sense of smell; yet they were there and should have excited any toxic action of which they were capable.

But granting all this, we have, of course, no argument against the hygienic importance of ventilation. It is the province of hygiene to secure and maintain the highest possible working efficiency of the individual, and we cannot doubt that, whatever the explanation or the mode of action, the air of a crowded, unventilated room is unfavorable to the highest working efficiency. We have here to try to answer the question, why is this air harmful?

The history of the subject shows clearly that the problem is not so simple as is often supposed. No doubt you are all familiar with the fact that the first attempt at explanation—that there is a deficiency of oxygen or an excess of carbon-dioxide in the air breathed—failed with the proof that in neither of these respects does the air of very badly ventilated rooms depart sufficiently from the normal to cause any physiological disturbance.† The settlement of this question cleared the ground for the search for the true cause, which was very properly supposed, as a provisional hypothesis, to be some abnormal constituent of the atmosphere, other than carbon-dioxide. The odor of the air proves the presence of abnormal constituents and its disagreeable character certainly suggests, although it by no means proves, that they may be harmful. One of the earliest experiments bearing on the subject we owe to Brown-Sequard. Air was aspirated through a series of bottles in each of which was placed a mouse. Between the fourth and fifth bottles the air was passed through strong sulphuric acid. Brown-Sequard reports that the first mouse to die was in the third bottle, while the mouse in the fifth survived without ill effects. It was plausibly assumed that the acid had removed some poisonous material other than carbon dioxide. The repetition of this experiment in the hands of competent observers has at times given similar results to those of Brown-Sequard and at other times given divergent results. Possibly this is to be explained by the differences in the rate at which the air is aspirated through the bottles or by some other uncontrolled condition of the experiment. It can hardly be doubted that, under the given conditions, toxic substances are added to the air; and, since these are removed by sulphuric acid, it is possible that they are of basic nature.

The presence of toxic constituents in the air of a crowded room is also indicated by experiments in which the water vapor of the air is condensed by cold and the liquid thus obtained is administered to an animal in one way or another. While the methods of work are decidedly open to criticism, it would seem that in many of them distinctly toxic and even fatal results have followed. In other experiments large quantities of the air of the room have been passed through sulphuric acid, the acid subsequently neutralized, and the liquid thus obtained has proved to have toxic properties.

Assuming that the positive results from experiments of this kind should be given greater weight than negative results, we are still justified in concluding that only the air of the crowded room contains some poisonous material. We are not justified in assuming that it comes from the lungs, since there is obviously the possibility of contamination from the skin, clothing, decaying food particles in the mouth, or catarrhal exudates from the air passages, and the like. This has an obvious practical bearing on the older teaching, that while the carbon-dioxide is not of itself poisonous, it indicates the quantity of poisonous material present. This cannot be true unless the poisonous material comes from the lungs; and there seems to be practical agreement that, when the respired air is received directly from the trachea of a normal animal, it is not only itself odorless, but there is no odor in the liquid obtained when the tracheal air is condensed by cold; nor do any toxic effects follow the administration of this condensed liquid to an animal.

As to what these toxic substances are we can only cite the experiments of Formanek, who detected in the air of a cage in which an animal was confined ammonia or ammoniacal compounds. These were not found, however, when the cage was kept scrupulously clean. The same observer reports that the administration of small doses of ammonium salts produces the same poisonous effects as the air of an uncleaned cage. We may conclude that if there actually is a poison in the air of a crowded room, it does not come from the lungs but from the skin, mouth, clothing, etc. It is also doubtful whether toxic material is regularly present. While this material may and probably does exert a toxic influence on those regularly living in poorly ventilated rooms, it does not seem to offer an adequate explanation of the symptons which develop within half an hour after entrance into the room. At the utmost the unpleasant odor of some of them may influence the working power by unpleasantly affecting consciousness; but there is no proof that the material giving rise to this odor exerts any *rapid* toxic influence, or even interferes with working power, so long as the subject is unaware of its presence.

In studying the physiological aspects of ventilation, it is of practical importance to distinguish between what may be called the acute effects of exposure of an hour or so to vitiated air, and those effects which are produced by prolonged exposure to such air. While the line cannot be sharply drawn between them, still it would seem that the toxic material acting for long periods of time should produce a cumulative undermining of health quite different from the immediate acute interference with the running of the human mechanism which all have experienced after half an hour's stay in a crowded room. I wish to suggest that the toxic material, so far as it is a factor, does harm chiefly if not entirely when it acts over comparatively long periods, and that we must seek elsewhere the explanation of the acute effects. They are sufficiently familiar to all; the dull heavy feeling; at times headache; the difficulty of sustaining attention, or even of keeping awake while listening to an address. Restlessness also develops, and this is often the expression of actual discomfort.

The symptoms are strikingly similar to those experienced in the warm muggy days of summer time, and in two respects the atmospheric conditions in the two cases are the same; namely, the high temperature and the high degree of humidity. Every breath of expired air leaves the nostrils at almost the temperature of the body, and saturated with aqueous vapor. The result is the most unfavorable of conditions for the maintenance of the constant temperature of the body, in the effort to maintain which resort is had to vascular and other adjustments, which, while successful in their immediate object, are unfavorable for other phsyiological activities. So important is this maintenance of the constant temperature that almost everything else, such as digestion, mental work, and the like is sacrificed to it.

A constant temperature means, of course, the maintenance of equality between the heat production and the heat output of the body. Heat production, when the body is not engaged in muscular activity, is, to all intents and purposes, constant above 68 or 70 deg. Fahr. At these temperatures it does not vary with external climatic conditions, and is not influenced by ventilation. The method of heat output, on the other hand, does vary with atmospheric conditions, and may be profoundly influenced by ventilation. It is so important to have this point clearly understood that, even at the risk of becoming tedious, I shall take the time to review the essential features of the physiology of heat output.

Heat is lost from the body chiefly in two ways. The first we may conveniently term *heat transfer*, and it includes the loss by radiation, conduction and convection; the heat thus lost is transferred to other objects the temperature of which is thereby raised. The second is by the *evaporation* of water, and in the body chiefly by the evaporation of the water of perspiration. The loss by heat transfer varies with the difference of

* Read before the American Public Health Association and reprinted from the *American Journal of Public Hygiene*.

† It should, however, be remembered that this is not the same thing as saying that oxygen deficiency or carbon dioxide excess has nothing to do with the ill effects, for the important thing is not the tension of these gases in the room, but in the lungs from which they are absorbed into the blood. It is conceivable that the consciousness of unpleasant odors, or other causes, may lead to more shallow breathing, this diminishing the volume of air breathed into the alveoli of the lungs and so cause lowered tension of oxygen and increased tension of carbon dioxide in the lungs despite the approximately normal content of these gases in air of the room. Haldane and Smith have given us a simple method of determining the composition of the air within the lungs, and it is desirable that this question be put to the test of nvestigation.

temperature between the body and surrounding objects. Hence, the rate of heat transfer decreases as the external temperature approaches that of the body, which latter would rise as the atmospheric temperature goes above 70 degrees, were not perspiration then secreted. So long as this perspiration can evaporate readily, there is little difficulty in keeping output equal to production. When, however, owing to high humidity evaporation is lessened, blood is rushed in larger quantities to the skin *at the expense of the flow to other organs;* the temperature of the skin is raised and so heat transfer by radiation, conduction, and convection is facilitated. The normal temperature of the body is approximately maintained; but it is at the expense of the working efficiency of other organs and especially that of the brain.

Between the circulation in the skin and that in the brain there is a very close correlation; one is generally, if not always, secured at the expense of the other. Thus sleep is accompanied by increased cutaneous circulation; waking is preceded by a sudden, marked cutaneous constriction. Mental work, especially that involving interest and attention, is accompanied by still further limitations of the flow of blood to the skin. Conversely, whenever the cutaneous vessels are made to dilate, as on the warm, muggy day, the quantity of blood flowing through the brain is lessened. In these facts we probably find the true explanation of the dull heavy feeling, the difficulty of attention, and the discomfort both on the muggy summer day and of the crowded ill-ventilated room. It is not impossible, too, that the unfavorable circulatory conditions in other organs as well as the disagreeable sensation of an overheated skin contribute to the interference with working power.

I would, therefore, conclude that the most important if not the sole cause of the acute effects of poor ventilation is the combination of high temperature and high humidity which then obtains. It is neither of these acting alone but *the two working together* which introduce into the system the unfavorable circulatory conditions we have described. It remains for us to consider in this connection a feature of the relation of high humidity to heat output, which has very important bearing on the practical problem of ventilation.

Humidity influences the output of heat from the body in two very different ways: It increases the conductivity of the atmosphere for heat—a cooling influence and it interferes with the evaporation of perspiration—a heating influence. What the net result will be depends on which of these influences of humidity is predominant. Below 70 degrees the second, or heating, effect drops out, because so little perspiration is then secreted, and a high degree of moisture chills the skin, as shown by the familiar effect of an east wind in winter along our northern Atlantic coast. Above 70 degrees, on the other hand, because conduction is slower, it becomes necessary to evaporate perspiration, and at these temperatures humidity heats the skin. Between these lower and higher ranges of temperature there is a neutral region at which high humidity has comparatively little effect. This region is about 68 degrees or 70 degrees. We have only to appeal to our own experience to see that high humidity chills the body at 65 degrees, while it is hardly noticeable (in the absence of muscular activity) at 70 degrees. In other words, so long as the temperature of a crowded room is kept at 68 or 70 degrees it makes little difference whether the humidity is high or low, so long as the occupants of the room are sitting still.

It follows from this that one of the most important, indeed, we may almost say, an absolutely essential object of ventilation is that of maintaining the optimum room temperature of 68 deg. to 70 deg. Fahr., and fortunately the temperature of a room, excepting warm weather is more readily controlled than the humidity. If the air is too dry it is a simple matter to raise its content of water vapor to the normal—and this should always be attended to. If, on the other hand, there is an excessive quantity of aqueous vapor in the room, there is no economical way of removing it, the least expensive probably being that of introducing very large quantities of dry air. If, however, the temperature be kept down to 68 degrees, high humidity may be largely neglected. I may here quote the actual experience of a friend of mine who had to secure good ventilation in a crowded lecture hall. He found that so long as enough cold air was pumped into the room to maintain the atmospheric temperature of 68 degrees or 70 degrees, every one in the room was satisfied with the ventilation, while complaints would come in as soon as the room temperature rose above 70 degrees. The quantity of air supplied was the same in the two cases; presumably the quantity of "poisonous exhalations" from the bodies of those composing the audience was also the same, and yet two or three degrees of temperature made all the difference to these people between good and bad ventilation.

When the room temperature cannot be kept down to the proper point by the introduction of cool air, fairly vigorous air currents must be maintained over the bodies of the occupants of the room. It is a matter of common experience that artificial systems of ventilation very frequently fail in warm weather, and the physiology of this is quite clear, for under these conditions ventilation must facilitate heat loss by favoring convection and evaporation. The "aerial blanket" of stagnant air must be removed, and the very virtue of not creating a draught when cold air is introduced becomes the fatal weakness of the ventilating system when we can introduce only air of a higher temperature than 70 degrees. The practical problem is an engineering one, but the conditions to be satisfied are perfectly clear.

SUMMARY

In this paper I have dealt only with the question of the deleterious conditions introduced into a room by the presence of human beings in it. It goes without saying that deleterious conditions may be introduced in other ways—from leaky gas fixtures, by the updraft from damp cellars, and so on. A large room which has been closed but not occupied may and generally does require the introduction of fresh air before it presents ideal climatic conditions for even a single occupant. Hence the ever present necessity of the renewal of the fresh air from without.

Within the limitations of our subject, I have tried to draw the distinction between the immediate or acute effects of poor ventilation and the more or less probable remote effects upon those staying for any length of time in rooms where the air is not renewed as it should be. I have shown that attempts to trace the *acute* effects of poor ventilation to the presence of toxic substances given off from the bodies of the occupants of the room have thus far been unsuccessful, although it does seem that prolonged exposure to some of these substances, especially ammonia compounds, may be responsible for the results of regular and prolonged exposure to vitiated air.

Whatever may be the actual role played by these emanations from the body, two other factors—one physiological and the other psychological—are of prime importance. These are the increase of temperature and humidity in the room, and the disagreeable sensation from unpleasant odors or from an overheated skin. The combination of high temperature and high humidity acts by rendering the output of heat more difficult, and the effect on the part of the body to maintain its constant temperature under these conditions introduces vascular and other conditions unfavorable to the efficient circulation of blood through the brain and other organs. The psychological condition of uncomfortable sensations may act purely as a psychological factor, but it may also, like so many feelings or emotions, react on physiological processes and so lower the standard of working power.

Finally, while the introduction of fresh air is of great importance, indeed is essential, we should remember that equally important is the maintenance of the ideal room temperature of 68 degrees to 70 degrees, since at this temperature the humidity factor is almost negligible.

Researches in the Value of Potato Varieties

The Use of the Microscope in Selecting Stock for Different Purposes

DR. PIERRE BERTHAULT, a prominent agricultural authority of Paris, gives the following points about a new method for determining the value of the potato. It will be remembered that the potato was introduced into Europe from America about 1584, but only two varieties seem to have been recognized up to the middle of the 18th century. At that epoch under the impulse given by Duhamel and Parmentier, the cultivation became more widespread, and the number of varieties soon increased. At the beginning of the 19th century there were 13 varieties known, then this increased to 177 in 1845 and to 212 in 1902. Recently, M. Vilmorin catalogued as many as 1,280 different varieties, and during the last ten years this number has grown, so that now about 1,600 varieties may be reckoned. Owing to so great a number of plants which have very different qualities, they must be properly classified so as to bring out the merits of the various types. But it is hard to make a proper grouping, as often these are but slight variations among the types of plants, and the color and the form of the potatoes do not give any aid whatever as to the quality or aptitude of these plants. Cultivators know, however, that there exist several well-defined types, and generally these may be placed in two classes, having in one class the plants with few tubers of a very fine taste, and in the second class the large and numerous tubers which have a large amount of starch, also intermediate varieties which partake of the nature of the two classes. In general, we may divide the classes into edible or industrial. It may then be asked whether the structure of the potato itself follows the same order as we find in practice. This Dr. Berthault claims to be true, and a microscopic examination of the tissues is quite convincing. When we examine a thin slice of a potato, it is seen to be made up of cells which surround and hold the starch grains. But these cells are of very different sizes according to the qualities of the tuber. Edible varieties show very small and numerous cells, while the industrial kinds are more loosely built up and have much larger cells. The intermediate kinds partake of both these structures. In this way much information is given by the microscope, and the author brings out the new quality of *cellular density*, which allows of grouping the potatoes according to the real nature. Cultivators as well as starch makers will find this idea of value in selecting the varieties which they need. Where a good-tasting potato is wanted, the varieties having small cells are selected, and to procure a large yield of starch on the other hand, the large-cell kinds are to be preferred. It is easy to take samples for the microscopic tests, as a simple cutting from the potato gives all that is needed and the same specimens can be then used for planting. For starch manufacture, this point is likely to be of much interest. For instance, three varieties which are often used, Magnum Bonum, Richter's Imperial and Blue Giant, are found to give very different amounts of starch for the same weight. The last kind furnishes less starch than the others. Such results seemed hard to explain, but they are now well accounted for when we examine the structure of the tubers. In fact the Magnum Bonum and the Richter's show an average of 36,000 cells per square inch, while the Blue Giant has nearly 50,000. It is reasonable to suppose that as the particles of the potato substance given by grating or otherwise scraping off during the manufacture are of the same size in both cases, the number of cells which remain intact and give up their starch with difficulty is greater when such cells are of smaller size, and thus a more considerable amount of starch is lost in the residues than where the cells are larger and more easily broken up. This accounts for the difference in the yield in the case at hand. These examples show the practical value of taking into account the cellular density and the important part it may be called on to play in estimating the value of potatoes for various uses. It seems to be proved, in fact, that the structure is a sure indicator of the qualities of the potato.

The Physiological Effects of Low Temperatures

Prof. Pictet has made extensive experiments in the endeavor to find out the effects of low temperatures on animals, animal eggs and vegetables, and has found that organism could withstand the lowest temperatures without undergoing any noticeable changes. The eggs of the silkworm could be cooled off to 40 deg. Cent. (below zero) without lessening their capability of development, while the eggs of birds were killed at a temperature of 2 to 3 deg. Cent. (below zero). It is well known that fish can be embedded in the ice of frozen rivers, and that such fish can be taken out and broken into small pieces as if they too were made of ice. But if the ice is allowed to melt slowly, the fish soon come to life and swim merrily around. They are able to endure a temperature of 20 deg. Cent. below freezing point. A snail remained alive after having been subjected for several days to a temperature of 110 deg. Cent. below zero; frogs will outlive a temperature of —28 deg. Cent. Infusorial animalcules can endure a temperature of —70 deg. Cent. and more, while bacteria, bacilli, spores and micrococci will bear a temperature of —200 deg. Cent., and if restored to normal temperature, develop in the normal way. It may be added that Prof. Pictet himself once exposed his bare arm to a temperature of 105 deg. Cent. below zero.—*Zeitschr. f. Kompr. Gase.*

Use of Vanadium for Rock Drills.—Among the many uses to which vanadium is being applied is the construction of rock drills. Not only the head, but also the cylinder and piston are made of vanadium steel.

The Swiss Railway to the Matterhorn

In the Heart of Picturesque Switzerland

For typical high mountain scenery, Zermatt stands second to none in Europe. The Bernese Oberland has its own peculiar charm, but among all its giant peaks there is none to be compared with the graceful Matterhorn, the tragedies of which are from season to season whispered all over the world until Zermatt itself has been crowned with universal fame as the "Paradise" of guides, whose sole study is how best to look after the wants of their cosmopolitan clients.

Mont Rose, 15,215 Feet Above Sea Level.

At present climbers are not by any means the only privileged visitors to this village in the heart of the Pennine Alps; for old and young alike ascend the valley of St. Nicholas by train from Viège 2,165 feet above sea level, which is in direct connection with Lausanne, and thereby with all the great European centers. The opening of the international line through the Simplon tunnel was of great importance to the traveler going to or from Italy, Zermatt is only sixteen hours from Paris, two and a half of which are taken up with the mountain railway from Viège to Zermatt, a distance of 22 miles, but a climb of 3,200 feet. The windows of the cars are large, so that every passenger gets a view of the magnificent scenery on either side.

The authorization for the construction of the Viège-Zermatt steam railway was granted by the Swiss Federal Council in 1886. The work was commenced in November of 1888, and the line was opened in 1891. The gage is one yard three and a half inches. The engine is of the Abt system, which consists of two machines capable of acting simultaneously; one of which acts by means of cog-wheels.

There are seven steam engines in service, all of which were made at the Winterthur Locomotive Works. They were constructed under the supervision of Mr. Roman Abt, and each engine has five brakes.

The cost of this steam mountain railway was over a million dollars. The construction of the line required the removal of 240,000 cubic meters of soil, of which 35,000 cubic meters were rock. It is claimed that since the opening of this line in 1891 only one slight accident has been recorded, for, the greatest care and caution are constantly exercised, in accordance with the special conditions and dangers inherent in the conditions of mountain railroading.

Leaving the Rhone Valley, the train follows the right bank of the River Viège. To the left is the old town of Viège, which has two churches, the one built specially for the nobility, who at one time had the power of appointing bishops and magistrates and exercised feudal rights.

The first station on the Viège-Zermatt Railway is situated where the main valley meets the Saas Valley. Beyond Stalden the railway passes through increasingly enchanting surroundings. Bridges and tunnels are frequent, but after crossing a 221 foot viaduct, 114 feet above the ravine of Mühlbach, the scenery becomes less wild until Kalpetran, 2,907 feet above the sea is reached. This station lies in a green expansion of the valley, beyond which the scenery extends in magnificent grandeur and the Viège, into the whole course of which over 70,000 acres of glaciers discharge their waters, rushes madly past.

From this point the mountains at either side grow more and more abrupt till St. Nicholas is reached, 3,678 feet high above the sea level. This is one of the most important villages of the valley. It suffered terribly, like the rest of the valley, from an earthquake in 1855. In 1749 the church was swept away by an avalanche. Only the tower was left. The sexton happened to be ringing the bell at the time, and when he came down from the tower, he was not a little surprised to find that, instead of walking into the church, he stepped into the open air.

The climate is the mean between that of the Rhone Valley and that of the high-alps. It is warmer than at Zermatt, and cooler than at Visp. In winter there is not usually at any time more than three feet of snow on the ground.

After passing Herbriggen, the engine has a steep climb of a mile and a half before it reaches Randa, 4,741 feet above the sea level. On the west of it is the Bies Glacier, descending from the Weisshorn; and on the east, the Festi Glacier, on the slopes of the Dome and the Nadelhorn.

Zermatt, 5,315 feet above sea level, is the terminus of this steam mountain rack railway. It is a little village surrounded by green pastures, many colored rocks and the dazzling whiteness of eternal snows. This journey from Viège to Zermatt is now accomplished by train in two and a half hours. In the old days of traveling by foot it used to take a little over nine hours.

The Matterhorn is to Zermatt what the Jungfrau is to Interlaken, what the Nile is to Egypt.

The summit of the Matterhorn was first conquered in 1865, after Prof. Tyndall and many others had failed. But, though Edward Whymper succeeded, it was at the cost of four lives; Lord Francis Douglas, whose body was never found; Mr. Charles Hudson, Mr. Harow, and Croz, one of the guides. Since then many other accidents have happened, but the Matterhorn is climbed every year by more and more men and women, for it has a greater fascination for the climber than any other summit in the Alps.

One of the highest electric railways in the world is the Gornergrat line. Since this was opened climbers are not the only ones to enjoy Switzerland's finest panorama. There are five trains up and five trains down daily.

As one naturally expects at a height of 10,289 feet,

Zermatt and the Matterhorn, 14,705 Feet.

everything is snow and ice. Glaciers extend below and around; and in the distance are many of the noblest peaks of the Alps, namely, Monte Rosa (15,215 feet), the Lyskamm (14,899 feet), and the Breithorn (13,686 feet), first climbed in 1813. The Matterhorn is 14,705 feet high, the Dent Blanche 14,318 feet, first climbed in 1862; the Weisshorn rises to 14,803 feet, while the summit of the Mischabels is 14,941 feet above the sea level.

The Gornergrat electric railway, which until recently was the highest in Europe, took two years to complete, a length of time due in no considerable degree to the height at which operations had to be conducted. From altitudes of 5,000 feet and upward there are practically only four months of the year available for work of this kind, and when blasting operations were forbidden at night, lest the visitors at Zermatt, where the line begins, should be disturbed, it would not have been surprising if the contractors had given up the project in despair. Instead, however, they proceeded to build barracks for their workmen at a height of 6,300 feet in order that the work of tunneling might proceed in the winter. These barracks were constructed of wood, and large enough to accommodate sixty workmen. The space between the

Hotel at the Gornergrat, Zermatt, 10,000 Feet Above Sea Level.

The Steam Rack Railway, from Viège to Zermatt.

double walls was filled with moss to keep out the cold, and to keep in the heat generated by two stoves burning night and day. By such means the men were kept in health and warmth throughout the long winter until the whole of the tunneling was completed.

In the spring the building of this electric mountain line was pressed forward and although the engineers had to contend with drifts of snow 20 and 30 feet high, the work progressed rapidly. No less than 11,000 men were employed on the line, and to their satisfaction the engineers saw the last stage begun before the autumn set in.

No diminution in the men's working power had been observed up to 2,700 meters, but above this height their health appeared to suffer somewhat. After the most difficult piece of work, the huge viaduct over the Findelenbrücke was completed, there was no longer any doubt as to the success of the undertaking, the ten kilometers of line were laid without interruption and the railway opened.

Electric power is generated by the water obtained from the Findalen Glacier, which possesses the great advantage of supplying more instead of less in hot weather. The cars are fitted with several brakes, one of which applies itself automatically should the speed exceed a certain limit. Each train holds a maximum of 110 people, and consists of two carriages (open and closed) and the electric locomotive. The total cost of the railway was more than half a million dollars.

Sixty years ago only twelve visitors had found their way up the narrow valley to Zermatt. By 1891, the year in which the Visp-Zermatt Railway was opened, the number had grown to 20,000 and now, with the electric railway in successful operation, more than 40,000 people take the trip to the Matterhorn in a single year.

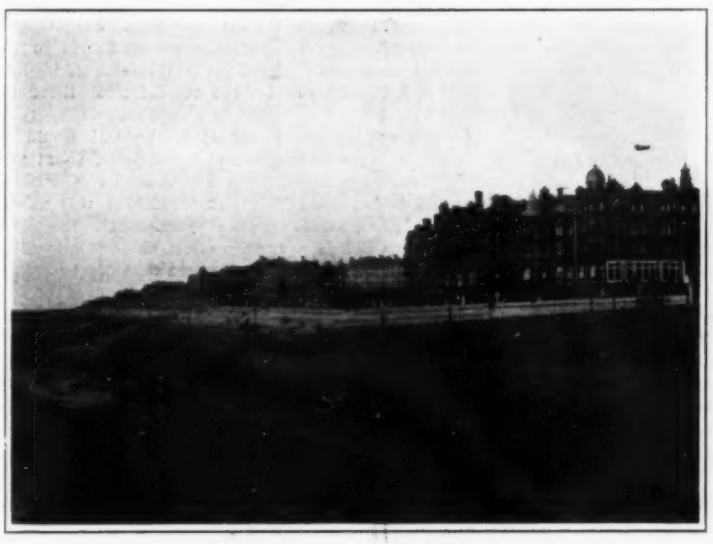
Blackpool Promenade Extension Works

Improvements At One of the Most Popular English Summer Resorts

By C. Van Langendonck

THE promenade widening work between North Pier and Cocker Street, at Blackpool, England, commenced in September, 1910, was completed in October last. The scheme comprises a promenade with a minimum width of 85 feet, and also terrace seats and a lower walk 30 feet in width, with a concave sea wall toward the sea.

The area of land reclaimed from the sea amounts to five acres. The main promenade has a width of 85 feet in the center and contains two sunken gardens at the south and north end, respectively, with a minimum space of 45 feet of promenading space round the garden. The sunken gardens are oval shaped, each about 300 feet long by 100 feet wide and are sunk 6 feet below the level of the promenade with steps and sidewalks as approaches. These gardens, in addition to being ornamental, afford shelter from the on-shore winds during boisterous weather. West of the main promenade is a fine terrace of seats and steps leading to the lower promenade. The seats are three tiers in height with landings 9 feet wide, and afford sitting accommodation for about 6,000 people. The lower walk commences at the north pier and descends by an incline of one in sixteen to the level of the north shore lower walk. From the lower walk there are six flights of steps, 15 feet in width, leading to the foreshore at an average level of about 20 feet below the level of the walk. A wide "slade" or inclined carriage-way, 30 feet in width and 750 feet in length, leads down from the main promenade level across the lower walk to the level of the foreshore at an inclination of one in thirteen, the total descent being of 52 feet vertically.



Finished Work, Showing Sea Wall, Apron and Terrace Seats.

Lower Walk and Terrace of Seats in Course of Construction.

The most important structural work involved by the scheme is the concrete sea wall and apron, which are necessary to support the huge mass of sand on the one hand, and to withstand the force of the sea on the other hand. This wall is over 400 yards long, varies in height between 26 feet and 37 feet, and is 11 feet thick at the base. The wall has been constructed throughout between the tides, and without any cofferdam work. It goes down 8 feet below the level of the sand, and is built entirely of Portland cement concrete faced with ballast stone. No reinforcement is used in the sea wall, as solidity and dead weight are both essential in such an exposed situation. It is provided with an apron throughout its entire length at a slope of 1 to 1½. At the toe of the apron ring, piles are driven 12 feet apart, to which the permanent walling and sheeting piles are secured. The apron is formed of consolidated sand covered with a layer of concrete 2 feet 6 inches thick, and faced with basalt stone grouted and bedded in cement mortar. Roughly 36,000 cubic yards of Portland cement concrete were used for the entire work, and the facing necessitated the use of 6,000 tons of basalt stone, while the sand for filling purposes amounts to 170,000 cubic yards.

The plant used in the work comprised: 5 steam locomotives, 100 side tip wagons, 4 steam loco-cranes, 2 steam pile drivers, and 4 steam pumps. The people employed varied from 300 to 350. The cost of the work amounts to about $250,000.

The promenades are formed by a layer of asphalt on a layer of concrete, and the slades are laid with granite cubes, while the slopes are pitched with rubble.

The Discovery of Porcelain in Europe

The Result of Accident in the Quest of the Philosopher's Stone

THE date of the discovery in Europe of porcelain, as distinguished from earthenware, is known quite exactly. In 1708 the professional alchemist Böttger of Meissen, acting under the "inspiration and assistance" of Augustus the Strong, Elector of Saxony and later King of Poland, produced the so-called red porcelain, using for the purpose Saxon earth. Incidentally remarked, this "inspiration and assistance" consisted in imprisonment, with the prospect of release only when he had discovered that "philosopher's" stone which would change lead into gold—the discovery of porcelain being a side issue. It was only by accident that Böttger arrived at the use of kaolin for "china" making. Report says that this happened by some of the powder from his wig—such powder being in fact kaolin or true China clay—falling into the fire. It was not until 1710, however, that he had succeeded in manufacturing white porcelain; or at any rate it was not until this date that he showed it in public—namely, at the great Leipzig "Messe" or fair. The raw material was for a long time imported; but later it was found that there was an abundant supply in Saxony itself.

But this discovery of Böttger, to whom a statue has been erected in Meissen (in the "Burg" or castle of which he had been imprisoned), was after all but the re-invention of an art which had been long known to the Chinese and Japanese—in fact, Chinese porcelain was in use on the table of the Elector Augustus himself. There had of course been many attempts to produce the thin-glass-like material; but all in vain—all that had been done before Böttger's time was to produce the so-called soft or "frit" procelain, which resembled the true porcelain in some particulars, and which was manufactured in France in the eighteenth century

Just how long the Chinese had possessed the secret which refused to disclose itself to the European inventors, has until very shortly been as much of a secret as the composition of hard porcelain was to the experts of the previous centuries; but now we can say that we know with tolerable certainty about when the Chinese commenced the manufacture of "China" ware.

It has long been supposed, by those who have studied the question, that the Chinese have known porcelain since the sixth century before Christ; this belief being based upon a statement by the French Jesuit Father d'Entrecolles, who had lived in the "Middle Kingdom," and who based his assertion on Chinese information. All belief in a still earlier origin—and this belief has long obtained among many who are interested in the subject—is based upon too little recorded evidence to be considered as of any value. The "Chinese porcelain"

found in 1834 in an Egyptian grave of 1800 B. C., proved to be a fraud of the commonest sort.

But now, having the advantage of long and careful research, Herr Ernst Zimmermann, Curator of the world-famous Royal Porcelain Collection in Dresden, has come to the conclusion, expressed in an article in the *Orientalische Archiv* that Chinese porcelain was invented toward the end of the fifth century of our era; and he names as the inventor the Minister of Public Works, of that time, Ho Chou. This Ho Chou is said to have been a collector and connoisseur of old paintings and the like, and to have had a very thorough knowledge of antiquities. This was at a period when unfortunately the art of glass-making had been lost for some time, as that of hardening bronze is to us; and while the workmen did not dare to make new experiments, he succeeded in making out of "green" porcelain, vessels which resembled the long wished-for glass. Records of the same period go to show that workmen then had succeeded in making vessels which were "white and brilliant as jade."

Prior to this time, says Zimmermann, the Chinese records concerning porcelain are scarce and unsatisfactory. During the Tang dynasty (618 to 907 of our era), on the other hand, there commences a series of praises of the ceramic manufactures of the time. Earlier records concerning ceramics can in no wise be considered as referring to porcelain; while there is no difficulty in recognizing in later descriptions the true hard porcelain. In fact, in the records above referred to, not only the time of the invention is mentioned, but even the way is pointed out by which it was arrived at, the production of a material the qualities of which lay between those of the previous ceramic wares and those of glass.

In any case, Böttger of Meissen was the first European who succeeded in producing, by ceramaic process, a ware "between glass and pottery." So we may set it down as proved that Ho Chou invented the true hard porcelain about the end of the fifth or the beginning of the sixth century after Christ; and that Böttger arrived at the same result about 1100 years later.

The Trajectory and Mass of Comets*

The Forces that Mold the "Bearded Meteor" and Its Path

By Henri Poincaré

WHAT is the origin of comets? Are they strangers in our solar system; do they traverse in all directions the vaster space that separates the stars? Are they messengers which pass from one constellation to the other, or are they highly eccentric satellites of our sun? In the last case, they must describe closed orbits or ellipses; in the first case, their trajectories must extend to infinity and form what are called hyperbolas. Most of them, as a matter of fact, travel in such extended orbits that it is impossible to determine whether these are closed curves or not, or, in other words, whether the comet will, at some future time, return to us or whether we are destined not to see it again; when I say "we," I mean, of course, our most remote descendants, for if the comet ever does return, it may be only after 10,000 or even 50,000 years. The calculus of probabilities, however, shows that if the comets did not belong to the solar system they should, in the majority of cases, have clearly and unmistakably hyperbolic orbits. Now, as a matter of fact, there is not one instance of which this is true.

The conclusion is that the comets have always belonged to our solar system; that they do not bring to us the news of other worlds that gravitate about the fixed stars. In general, they describe very much more elongated orbits than the planets and recede very much farther from the sun, and we may take it that they take many thousands of years to make one complete revolution. Halley's comet returns once in seventy-five years; there are others whose return is more frequent, occurring, for example, every six years. What is the cause of this? Have these comets of shorter period a different origin from the others, an origin which would place them in an intermediate position between comets proper and the planets? Not in the least; in bygone ages they, like the others, took thousands of years to traverse their orbits, but in the course of their history they have met with a mishap. They encountered a large planet. By this I do not wish to imply that they collided with it. They simply passed sufficiently close to it to have their trajectory profoundly altered. Thrown aside from their regular path, they have left the great elongated ellipse on which they formerly traveled, to follow another smaller ellipse, more nearly approaching a circle, which they can cover in a shorter period of time. In this way Halley's comet has been "captured," as the expression is, by Neptune, and most of the other perodic comets by Jupiter. What, then, is the future of comets? We see the planets gravitating around the sun without undergoing any appreciable change. No doubt they are not eternal—they will some day perish, but that day is very far remote. These bodies rapidly approach their doom, and we have seen some of them disappear before our very eyes. Thus there was a certain comet, the Biela, which had been captured by Jupiter and which returned every six years. During one of its returns, some fifty years ago, after observations had been rendered impossible for several days, through bad weather, it was re-sighted, divided into two parts by some unknown cataclysm. The two nuclei seemed to be drifting apart. They were again seen at a subsequent observation. Six years later the comet was again expected, but it did not return, nor has it been seen since. Instead of the defunct comet, however, and in its place, a shower of shooting stars comes at regular intervals. If the orbit of these shooting stars is calculated, it is found that it coincides with that formerly followed by the comet. Schiaparelli, the great Italian astronomer who died recently, has generalized this result. He has established the fact that the orbits of a large number of meteor swarms are closely related to those of comets, either living or dead. The coincidence is, of course, not quite perfect, for since the comet did not actually strike the earth, we would not see the meteorites if they did not diverge to some slight extent from the original orbit. For the rest, these shooting stars follow approximately the orbit of the comet and are distributed all along this curve, trailing behind the original position of the comet from which they arose.

This reminds me of a story of the end of the world. The Leonid swarm revolves in the orbit of the comet of 1866. Shooting stars are seen every year on November 13, but every thirty-three years the number of meteorites seen is the maximum, because the period of revolution of the comet is thirty-three years. Now, certain well informed newspapers had announced that the end of the world would take place on the 13th of November, 1899. Quite crestfallen, a journalist came to interview me, and I reassured him by telling him that the same phenomenon had occurred in 1833 and 1866. Thus comets are gradually disintegrated and end by being resolved into a swarm of shooting stars; how is it, then, that there are any comets left after all this lapse of time since the world began? The fact is that this slow destruction of the "bearded meteors" appears to occur only at the moment when they pass near the sun. So long as a comet passes its perihelion only once in some 10,000 years, for example, evidently it may for a long time escape destruction; but if once it is captured by a planet, as we noted above, the comet becomes periodic, approaches nearer to the sun and returns once in a century, or may be once in ten years, to bask in the sun's rays. Henceforth its days are numbered and the work of death proceeds rapidly.

Why, it may be asked, is it that comets have tails? The fact is, if they had no tails, no one outside of the astronomic profession would take any notice of them. All sorts of more or less absurd solutions have been proposed for this problem. There is one which at present is in fashion and which appears to rest upon sufficiently good foundations to make us wonder whether it may not be destined to survive. Some explanation is required. Maxwell, starting from theoretical considerations, had arrived at the conclusion that light must repel bodies upon which it falls. Subsequently Bartholi, starting from an entirely different base, reached the same conclusion. It remains for these hypotheses to be verified. The difficulty arises from the extremely small magnitude of the repelling force in question. It is with this end in view that the well-known radiometer* was devised. It was hoped that it would turn under the influence of light, as theory demanded. Indeed, it did turn. In fact, it turned much faster than was expected. Unfortunately, it turned in the wrong direction. There was, therefore, an effect which no one had foreseen, which was much greater than that which had been calculated, and which completely masked the looked-for effect. The cause had to be discovered. This was achieved without very much difficulty. The rotation was due to the movements caused by unequal heating in the extremely rarefied gas which enclosed the radiometer vanes.

Next an attempt was made to eliminate this disturbing effect by using very thin vanes, silvered on both sides. The apparatus did not turn, but suffered a slight deflection. I have been told this deviation is in accordance with the theory.† I have also heard of a still more striking experiment. A mixture of iron filings and lycopodium powder is allowed to fall through a sand glass; at a given moment a beam of light is directed upon this mixture; the iron, which is heavier, continues its vertical path while the lycopodium, repelled by the light, is deviated and separated from the filings. We have there, it appears, an artificial reproduction of comets' tails. The iron filings represent the nucleus formed on heavier matter, which continues in its elliptic orbit, like a well-behaved planet. The lycopodium corresponds to the tail, which, instead of following this ellipse, is deviated and thrown out by the repulsion of the sun's light.

According to this explanation, the tail would be formed of extremely attenuated particles, so attenuated that this repulsion overcomes the Newtonian attraction. It must be remembered that this attraction is proportional to the mass, while the light pressure, which is a surface effect, is proportional to the surface area. If, therefore, we consider two stars, of which the larger has twice the radius of the smaller, this larger star will be attracted with eight times the force and repelled with four times the pull of the smaller one. It is therefore possible, under the right conditions, that repulsion may predominate in the case of the smaller, and attraction in the case of the larger, star.

And what may be the dimensions of these particles? We can form some idea of this. A Russian astronomer, Mr. Bredichin, has made a study of the form of comets' tails. He recognizes the fact that the theory given above should account for this form. The curvature of the tail is variable, no doubt according to the composition of the particles, the curvature corresponding to different types of particles, of which the repulsion is, say, five times, ten times, twenty times, etc., greater than the attraction. And what dimensions are we thus led to ascribe to these particles? This depends on the density which we attribute to them. However, it must be remarked that they cannot be gases, for gases are transparent and allow the light to pass through them without being affected thereby. The material of which the comet's tail is composed is regarded as either solid or liquid, and rather arbitrarily the density of petroleum has been attributed to it, no doubt partly because hydrocarbon lines are found in its spectrum. Calculation then shows that the diameter of these bodies must be about of the order of one thousandth of a millimeter. The several types of tails noted by Bredichin accordingly correspond either to particles of different diameters or to particles formed from substances of greater or less density.

We now see how we must conceive the genesis of cometary tails. Such a tail is like a plume which the nucleus carries along with it. But there are, as it were, two kinds of plumes—such plumes as soldiers wear on their helmet, and the tuft of smoke issuing from the funnel of an ocean steamship. The plume of the soldier travels with him, and the material of which it is made retains its identity. A casual observer might think that the same was true of the tuft of smoke from the steamship, since he might note that the steamer had gone from New York to Havre without leaving behind it any permanent trail. And yet we know quite well that this is not the case, that the smoke would be promptly dissipated if the stack did not continue to furnish new quantities to replace those which disappear. The smoke which arrives at Havre is not by any means the same as that which left New York.

The tail of a comet resembles the smoke of a steamship. It is not a great sword with which the comet cuts through space. At every instant, through some unknown cause, and no doubt under the influence of

*Paper read before the Industrial Society of Mulhouse and published in *Cosmos*. Translation prepared for the SCIENTIFIC AMERICAN.

*The radiometer here referred to is the instrument commonly seen in opticians' windows, and consists of a set of delicate mica vanes blackened on one side and rotating under the influence of light falling upon them.—ED.

†The author apparently here refers to the very brilliant experiment of Nichols and Hull, performed in this country, which established beyond doubt the existence of this very minute pressure of light, and furthermore demonstrated quantitatively the accord of the observed effect with Maxwell's theory.—ED.

the sun's heat, particles are detached from the nucleus, and the comet fritters down, so to speak. When the particles are detached, their very lightness exposes them to the repulsion of the sun's light, and they recede into space and are lost. The tail would soon disappear entirely if it were not continually regenerated anew.

Under these circumstances it is readily intelligible that an encounter with such a tail need cause us no anxiety. In the first place, the mass of comets is not very considerable. It has now been observed that it does not exercise the slightest perturbating influences upon the planetary orbits. A comet on a certain occasion passed between Jupiter and its satellites. Its trajectory was strongly modified, but neither Jupiter nor its satellites seemed to be in the slightest degree affected. La Place went so far as to say that the mass of a comet is only a few kilogrammes. In this he evidently exaggerated. An encounter of a comet's nucleus with the earth would no doubt cause some damage, but such an event is extremely improbable, for the nuclei are relatively very small, and we really stand very little chance of hitting such a small target. The same is not true as regards the tails, which spread over an immense space in the sky, but then their density is negligible, as can be readily shown. The contrary might be supposed, in view of the light which they emit. Even if we admit the whole of this light is reflected sunlight, and that no cathode phenomena such as may occur in highly rarefied space, enters into the case, there really is no cause for anxiety.

If we consider a given mass lighted up by the sun, the amount of light which it reflects will be the greater, the more highly divided its substance. If this mass is formed of a large number of small spheres, the reflected light will be the more intense, the smaller the spheres. It is easy to realize this; let us imagine larger spheres of two centimeters radius, and smaller spheres of one centimeter radius; the volume or mass of the larger spheres will be eight times that of the smaller spheres, but the surface of the larger spheres will be only four times that of the smaller. Eight small spheres, therefore, will be equivalent to one of the larger ones in point of mass, but they will have twice the surface area and will therefore reflect twice as much light. The moon has a radius of something over 1,000 kilometers,* and the particles which we are considering measure one-thousandth of a millimeter in diameter. If, therefore, we were to fill the volume of the moon with particles of this magnitude in such manner that the total density were one million million times less than that of the moon, the light which would be reflected would still have the same brilliancy as that which we receive from the moon. If we viewed this collection of particles at the distance of the moon, they would present just the same appearance as the moon. If we were farther away we would see them smaller, but with the same brightness. As a matter of fact, the brightness of the comet's tail cannot be compared with that of the moon. It is, may be, one hundred times less, perhaps one thousand times—I am not aware that any measurements have been made. We must, therefore, conclude that the density of the particles is 10^{18} times less than that of water; we might as well say that we have, in the comet's tail, nothing but empty space, since it represents a density over one thousand million times smaller than the most extremely rarefied gas which we are able to produce in a vacuum apparatus with the most perfect means which modern technique places at our disposal.

*The eminent French mathematician has here taken considerable liberties in rounding off his figures. As our readers know, the Moon's radius is 1081 miles.—ED.

Wheels, Ancient and Modern—II.*

From Log Roller to Wire-spoke Motor Car Wheel

By Henry L. Heathcote, B.Sc.

Continued from Supplement No. 1877, page 415

MODERN WHEELS.

The Suspension Wheel.—We will now pass on to the next stage in wheel development, which dates from the use of bicycles. During this gap of about 2,500 years the only changes of any importance were the dishing of wheels to resist lateral stresses due to ruts and rounding corners, and arranging the spokes on two cones instead of one. This last was done as early as 1828, and is still practised at Woolwich Arsenal in building ambulance wagon wheels. Strange though it may appear, wheels were not used generally for facilitating transit in Britain till comparatively recent times. The very first carriage was made for Queen Elizabeth in 1568; the first that plied for hire in London were in 1625, and the first stage coaches were in 1659. Broadly speaking, all the early wheels were compression wheels with radial spokes. The introduction of the suspension wheel for bicycles marked a great advance in the shock-absorbing powers of wheels. The first bicycle wheels were compression wheels, and had wooden spokes and rim with an iron tyre. The wheels were just ordinary light carriage wheels. The curved member connecting the back axle to the top of the front wheel is not altogether unlike that used in the chariots of the ancients. Later bicycle wheels had radial-wire spokes which, being in tension, kept the rim in position. In the older wheels the rim was normally in tension, and the spokes and hub in compression. In a suspension wheel the spokes and hub are in extension, while the rim is in compression. It is a common, though not unnatural error to suppose that the spokes of a modern bicycle wheel are sometimes in compression. As a matter of fact, they are always in tension, even those between the hub and the ground, when a heavy rider is in the saddle.

Fig. 1 represents one element of a wire wheel. If tension be applied to the spokes, the rim and hub would move toward each another were it not for the effect of the other segments; the resistance to the compression forces in the rim, and to the bursting stress in the hub shell prevents this movement. When compression is applied between the bottom of the rim and the hub-center of such a wheel, the tension of each spoke will, if the rim is inflexible, decrease proportionately to the

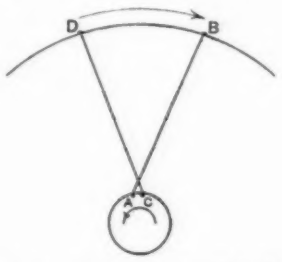


Fig. 1—The Torque Applied at the Hub Must be Transmitted Along the Wire Spokes to Overcome the Resistance at the Circumference.

cosine of the angle between the spoke, or, rather, the projection of the spoke in the plane of the wheel, and the direction of compression. When the cosine becomes negative, as when the spoke is above its horizontal position, the decrease becomes, of course, an increase, having its maximum for spokes on the upper part of the wheel pointing in the direction of the compression. Obviously the spoke tension should never fall to zero nor rise above the elastic limit, and these limits help to regulate the choice of the initial spoke tension.

The Tangent-Spoke Wheel.—The tangent-spoke wheel in which the spokes are tangent to a circle having its center at the axle and are not normal to the rim, probably owes its origin to the curved arms used in driving pulleys and fly-wheels for transmitting considerable torque. Both ancient and modern *radial* spoke wheels are capable of transmitting a certain amount of torque, but the amount is limited, and depends not only on the bending strength of the spoke, but on the rigidity of its attachment to both rim and hub. Since no material has an infinite elasticity, it follows that however thick the spokes may be there must be a certain amount of twist of the hub (in the plane of the wheel) relatively to the rim, or no drive can be transmitted. When the torque is considerable—as in a motor car wheel—the actual twist sooner or later rises above that corresponding to the elastic limit at some or all of the spoke attachments, and this leads to gradual loss of rigidity and to creaking, and, in some cases, even to charring, owing to rubbing. In a radial-spoke bicycle wheel subjected to a torque in its plane, the hub must rotate relatively to the rim until the spokes are tangent to a small circle.

If the average tension on the N spokes is t, when transmitting the torque T the tangent circle will have a radius—

$$r = \frac{T}{Nt} \text{ approx.}$$

Applying this to a bicycle wheel with fifty spokes, and assuming the pull in the chain to be 300 pounds (which is about that due to a vigorous jerk), the chain ring to be 3 inches diameter and the hub flange 1¾ inches diameter, if the average final spoke tension be 80 pounds, it is easy to show that the hub will twist 7.35 degrees relatively to the rim.

In a tangent-spoke wheel the hub must also turn relatively to the rim, but the angular movement is far less. In this case torque has the effect of increasing the tension on half the spokes and decreasing it on the other half. Reverting to Fig. 1, if the initial tension on $A\ B$ and $C\ D$ be t and the added and subtracted tension be p, the torque due to—

$A\ B$ will be $(t + p)\ r$, and to
$C\ D$ will be $(t - p)\ r$.

The difference of these is the resultant torque due to this element—

$$\therefore \text{Total torque} = \frac{N}{2} \times (tr + pr - tr \times pr)$$

$$\therefore T = N\ p\ r.$$

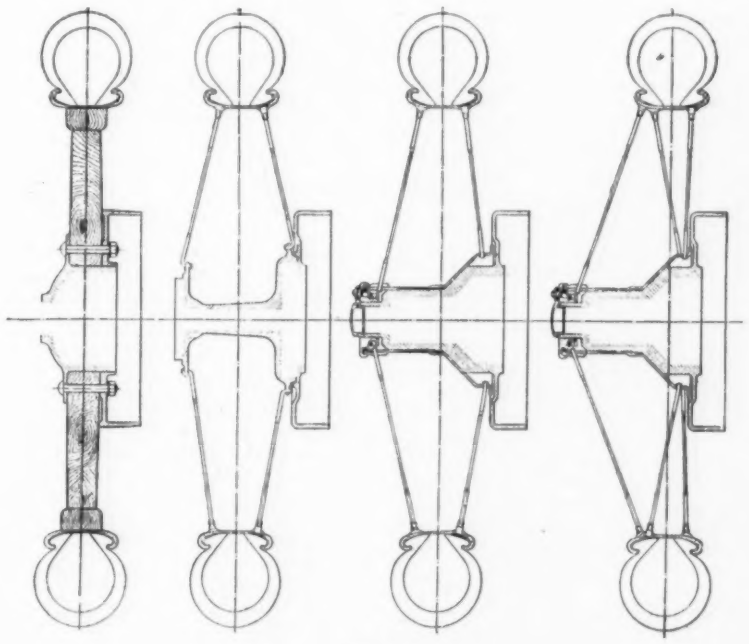


Fig. 2.

Fixed Wood Wheel. A Very Common Type.

Fixed Symmetrical Wire Wheel. Double Spoked.

Rudge-Whitworth Patent Detachable Wire Wheel, Patent Dished Construction, Double-Spoked.

Rudge-Whitworth Patent Detachable Wire Wheel, Patent Triple-Spoked Construction.

* Paper read before the Royal Society of Arts and published in its *Journal*.

Which is independent of the initial tension t provided $(t - p)$ is a positive quantity.

If the tangent circle be of the same diameter as the flange in the previous case, it is easy to show that, for fifteen-gage spokes elasticity 10,000 tons per square inch, the twist of the hub for the same push as before will be 0.11, degrees or about one-seventieth that with radial spokes. This greater rigidity in torque transmission places the tangent-spoke suspension wheel far ahead of both radial compression and radial tension wheels. It

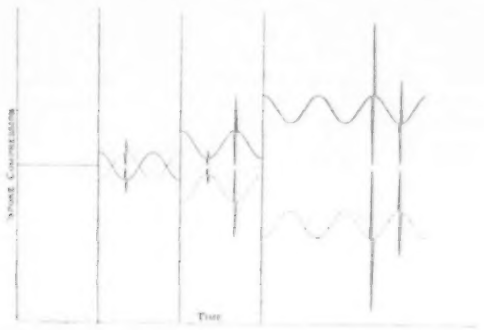


Fig. 3—Diagram Showing the Tension of Two Diametrically Opposite Spokes as a Function of the Time, Under Various Conditions.

has long been universally used for bicycles and motor bicycles, and is now enjoying unrivaled popularity in its application to motor cars.

The radial wheel has to be subjected to great radial tension or compression in order to impart the necessary torque rigidity. In the tangent wheel the necessary torque rigidity can be attained without imparting excessive radial rigidity. As a result of this the tangent suspension wheel can be made capable of absorbing shock. A comparison of a suspension wheel with a section of a tyre will bring this out more clearly.

SUSPENSION WHEEL AND TYRE SEGMENT COMPARED.

The deformation of a tyre by load is resisted because the radially-acting air pressure puts the tube and cover in considerable tension. The rim of a suspension wheel is the reciprocal of this, being in compression due to the radial components of the spoke tension. The rim flattens like a tyre under load or shock, the radial tension in the one case acts like the air pressure in the other; the greater the tension the less the rim flattens, and the less the tension the "softer" is the wheel.

Wheel building is the counterpart of tyre inflating, and the art produces its best when sufficient tension to produce torque rigidity is combined with conditions that develop in the wheel a maximum cushioning effect. Such a wheel, by co-operating in the duties of the tyre, lengthens its life and lessens its liability to wear, cuts, and punctures. To obtain maximum cushioning from a wheel of this type, moderate spoke tension needs to be combined with a flexible and resilient rim and thin spokes. This in its turn implies not only careful choice of materials, but appropriate design to neutralize the reduction of resistance to torque perpendicular to the plane of the wheel entailed by lightening the rim. Both the wheels of antiquity, modern artillery wheels, and wheels for motor-cars, owe much of their lateral strength to the high moment of inertia of their heavy wooden felloes, the disadvantage of which is their inflexibility and consequent inability to absorb shock. The Rudge-Whitworth wire wheel for motor-cars (Fig. 2) is the first wheel in which these requirements were adequately met. This is done by making the outside spokes, that are much dished, enter the rim near its edges and not at its center, as was formerly considered correct. In this way members are provided to oppose the twisting of the rim due to sideways shearing of the tyre when rounding corners.

It is only fair to add that this method of spoking has the effect of localizing the bending stresses, due to the pull of the tyre bead, in the edge of the rim. This is met by strengthening the rim bead, which at the same time strengthens the whole wheel very considerably.

There is another point of similarity between the wire wheel and a tyre segment. If the radial compression on tyre walls gradually decreases owing to air escaping from the stressed condition, the flexed part of the tyre will be increased, and a point arrives at which this has to be neutralized by inflating. Similarly, if the spoke tension of the wire wheel should fall the flattening of the rim would increase, and might even reduce the spoke tension to zero.

Fortunately, solids are more easy to manage than gases, and by employing spokes of high elastic limit, and by cold working the metal of the hub shell round the spoke heads, and of the rim round the nipple holes by hammering and bulging (coupled, of course, with proper design and materials), the vibration elastic limit above which permanent escape and loss of tension would occur, is made so high that after a slight initial bedding the ordinary stresses are insufficient to "soften" the wheel. In any event, the spoke tension can be adjusted readily. It is not to be supposed that even a wheel of this advanced type is capable of absorbing as much shock as a tyre. The air pressure in the inner tube of a motor tyre ranges usually from about 60 to 90 pounds per square inch, but the corresponding normal pressure on a Rudge-Whitworth wire wheel rim ranges from about 150 to 200 pounds per square inch. This, combined with the fact

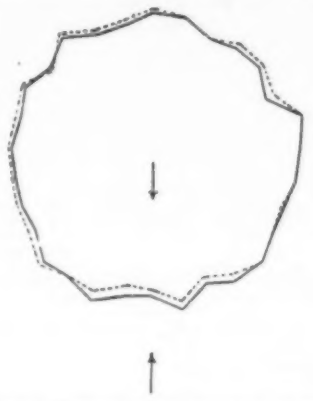


Fig. 4—Polar Diagram of the Tension on the Spokes of a Rudge-Whitworth Detachable Wheel.

that the rim is not nearly so flexible as a tyre cover, accounts for its inferiority to the tyre as a shock absorber, though the much larger diameter of the wheel operates in the other direction. Large diameter wheels—like large section covers—are, *ceteris paribus*, better shock absorbers than small ones. The superiority of this type of wire wheel as a shock absorber, compared with compression wheels with radial wood spokes, is a matter of actual experience as well as of conjecture, and is noticed in their more constant contact with the ground under similar conditions of use.

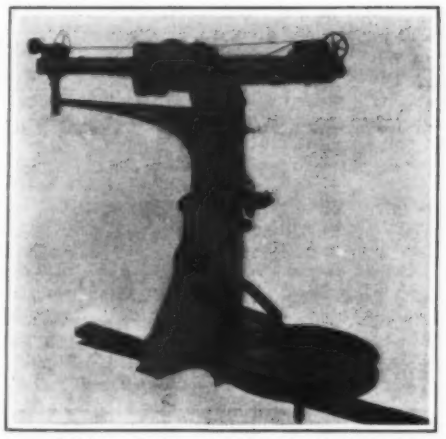


Fig. 6—Denison Testing Machine to Imitate Stresses Set Up in Rounding Corners or in Side-slipping.

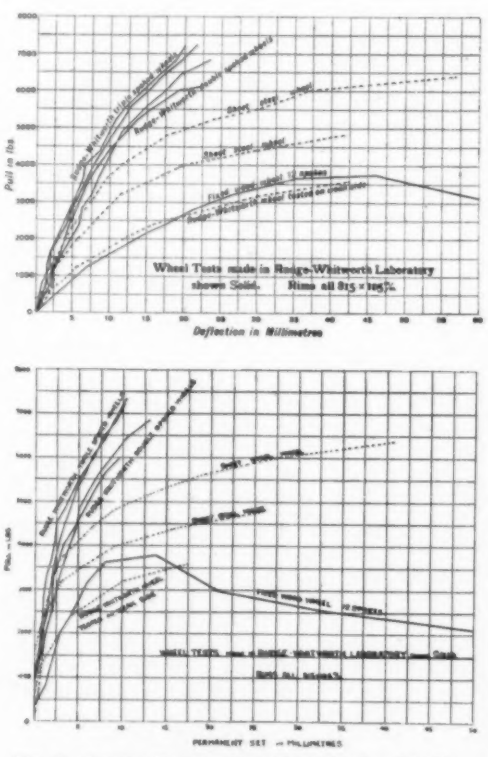


Fig. 7—Curves Representing Tests Made with the Denison Machine.

EVOLUTION OF THE MOTOR-CAR WIRE WHEEL.

The first wire wheels to be used for motor-cars were bi-laterally symmetrical like the front wheel of a bicycle. The spokes were headed and bent near the head through 90 degrees (see Fig. 2). The holes in the hub flanges were drilled parallel to the axle, and the spokes threaded through these holes were attached to the rim by nipples screwed on to the other end of the spoke. But, as in

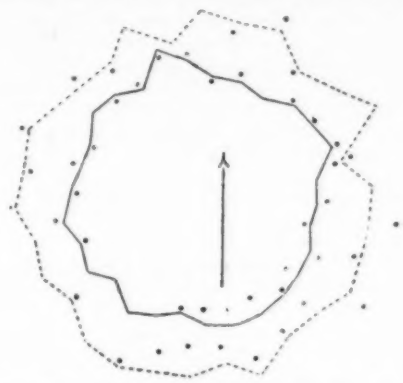


Fig. 5—The Full Line Indicates the Initial Tension on the Outside Spokes, the Dotted Line that on the Inside Spokes. The Dots Show the Effect on the Tension Produced by a Combined Load and Torque.

living structures, so in engineering constructions, evolution brings gradual morphological differentiation of structure and further division of labor. In the early bi-laterally symmetrical wire wheels both inside and outside spokes transmitted the drive. In the present Rudge-Whitworth wire wheels, to prevent the stresses rising too high when rounding corners or when skidding, the wheels are dished and the outside spokes are relieved of the whole or greater part of their share in transmitting drive. This is done in some types by making the hub of much larger diameter at the end near the car than at the other end. As a result of this the displacement of the inside spoke heads under torque is greater than the displacement of the outside spoke heads, the ratio of the displacement in the direction of the spokes (and therefore of the added tension) being the ratio of the diameters of the circles to which the spokes are tangent. In other types the end of the hub to which the outside spokes are attached is revoluble, so no torque is transmitted by them and their whole strength is reserved for resisting side-thrusts.

Another departure from symmetry which secures greater strength for the inside or driving spoke cone is the employment of 50 per cent more spokes inside than outside. In the hub shells the spoke holes are not drilled parallel to the axle, but perpendicular to it. This enables spokes bent through a small angle to be used; for instance, the inside spokes that transmit the drive are only bent through 45 degrees, and this, with a special way of producing the bend and careful scrutiny in the firms' laboratory, has enabled the strength at the bend to be increased from about 60 per cent (with the 90 degrees bend) to over 90 per cent that of the body of the spoke. The outside spokes are bent through less than 45 degrees so the strength at the bend is still less impaired. Another improvement is the addition of another cone of spokes, making three in all, so that the drive is transmitted to both sides of the rim. The same device enables the point of contact with the ground to be more nearly under the bearing or steering knuckle (see Fig. 2).

The diagram of Fig. 3 illustrates the fluctuations of spoke tension (or compression in a compression wheel) under some of the conditions of use, assuming that the rim is *not* flexible. When the wheel is jacked up, revolving does not appreciably alter the spoke tension which, therefore, does not vary with time, and so is represented by a horizontal line, as shown in the first section of Fig. 3. When the car is in steady motion and free-wheeling the tension on each spoke will increase and decrease, the values following a cosine curve (as already explained), the X axis of which should be below the minimum points. The zig-zag, which occurs at different points of the curve in Fig. 3, illustrates the effect of a shock due to the wheel leaving the ground and falling back suddenly to its former condition. The dotted line shows the instantaneous condition of a spoke diametrically opposite.

In the third section we see the variations in tension of the spokes of a driving wheel traveling straight; and the fourth shows the variations when the wheel is being driven round a corner. It is important to notice that the effect of the same shock is very different in the different cases, and depends on the instantaneous value of the spoke tension as well as on the position of the spoke in the wheel. The variation set up in a wood wheel will follow the diagrams pretty closely, but actual experiments with wire wheels show that the increment of tension due to load, torque, and load and torque com-

bined, is not nearly so great as those diagrams indicate.

EXPERIMENTS WITH WIRE WHEELS.

Fig. 4 shows a polar diagram of the tension on the spokes of a Rudge-Whitworth detachable wheel fitted with a tyre sustaining a load of one ton. About one-quarter of the spokes have their tension relieved, but the others experience nothing like the same increase, and it is distributed fairly evenly all round.

To test the effect of combined load and torque, the pull was applied to a dummy tyre made of iron, so that its line of action did not pass through the center of the wheel. By varying the distance between the wheel center and the line of pull the ratio $\frac{\text{torque}}{\text{load}}$ could be varied at will. In this way tests imitating all sorts of conditions of road surface, car load, and horse-power engine have been carried out.

Fig. 5 shows a polar diagram for a wheel having the same number of outside and inside spokes, the outside spokes of which transmit their pull to the hub and not to a revoluble ring. The outer dotted line indicates the initial tension on the inside spokes, the inner that on the outside ones. The dots show the effect on the tension of the combined load and torque. In this test the inner hub, hub-shell nipples, and rim are all tested, and the results demonstrate beyond controversion the enormous strength of these wheels for forces and couples in the plane of the wheel. The point to which I would particularly call attention is the great advantage of a flexible rim which, as these results show, quite obviates the high tensions or compressions which would otherwise obtain, and which would prove so destructive every time the wheel was jerked off the ground.

In addition to determining the effect of load and torque, separately and combined, we have subjected both wood and wire wheels to a side-pull applied at the rim or to a dummy tyre. Fig. 6 shows a Denison testing-machine, adapted to imitate the stresses set up in rounding a sharp corner at very high speed or in a bad side-slip. The results of some of these tests will be seen in Fig. 7. In nearly every instance the deflection of the wood wheel for the same pull is greater, and in every case the wood wheel sustained permanent damage at a lower pull than in the wire wheel. The same applies to the sheet-steel wheels. The arrangement of the spokes in the Rudge-Whitworth wire wheel has been the subject of careful design and experiment. Fig. 8 shows the results of some of these experiments, and makes it clear that the strength attained, even with precisely similar rims, hubs and spoke material, depends greatly on the design selected. These tests have given valuable data as to the best designs and materials for the rims, spokes, and hub shells. It does not follow, however, that designs and materials proved suitable for withstanding a steady force are also suitable for impulsive forces, so the various types of wheel have been investigated under impact.

For this purpose use is made of an impact pendulum, which is released against the top of the rim of the tyred wheel. The length of the pendulum is about 12 feet and the bob weighs nearly a quarter of a ton. In some tests increasing blows were applied to the same part of the wheel, in others a moderate constant blow, e. g., 200 foot-pounds—was applied at successive points on the rim eleven-thirtieths of the whole circumference apart. Fig. 9 shows characteristic diagrams for wood, wire and sheet-steel wheels subjected to increasing blows at the same place; and Fig. 10 shows the results of testing wood and wire wheels with similar blows, the wheel being turned eleven-thirtieths of the way round after each blow.

The question will probably suggest itself as to whether a motor-car wheel is ever called upon to stand side-thrusts and blows as great as those represented by the upper part of Figs. 7 and 9. The magnitude of the stress depends in every case, not entirely, but primarily, on the force that the ground can exert on the wheel. For

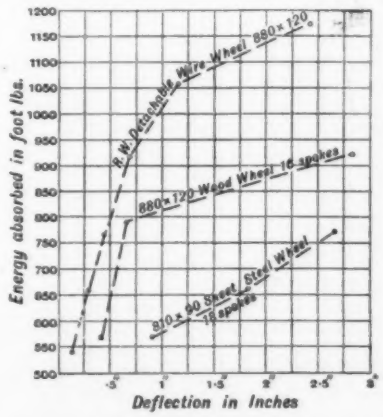

Energy absorbed in foot lbs.
Deflection in Inches
R.W. Detachable Wire Wheel 880×120
880×120 Wood Wheel 16 spokes
810×90 Sheet Steel Wheel 16 spokes

Fig. 9—Behavior of Wheels Under Successive Blows Applied to the Same Point.

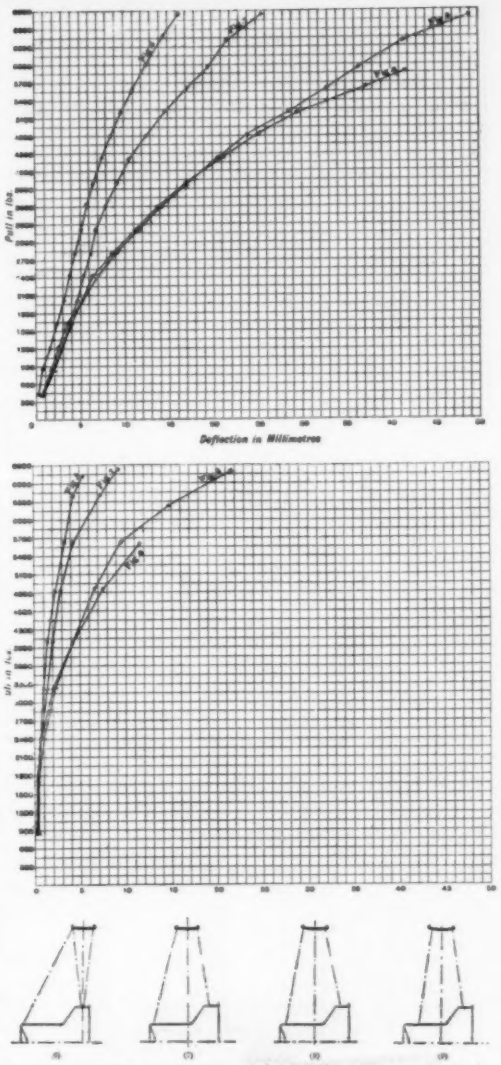


Fig. 8—Tests Showing the Influence of Design of Hub and Spokes when the Material is the Same.

instance, the forces that turn a car round a corner reside in the round. It is quite a mistake to suppose that the driver at the steering-wheel really steers the car; the path followed may be *indicated* by the steerer, but it is *dictated* by the ground. The most the driver can do is to turn the wheels into such a position that, if the ground permits, the forces developed under and near the wheels will alter the direction of the car to the desired extent.

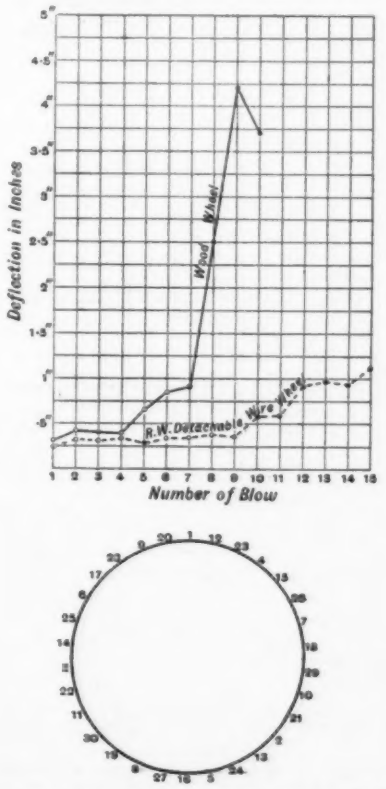


Fig. 10—Behavior of Wheels Under Successive Blows Applied to Successive Points on the Circumference, in the Order Indicated on the Circle.

The stresses set up when rounding corners without skidding have been very fully investigated by J. V. Pugh (*Autocar*, 1906, pages 910 and 948). When traveling at twenty miles per hour round a curve 30 feet radius, the side-thrust on an outside wheel, at the tyre, may be as much as 1¼ times the load on the wheel when traveling straight. When skidding, the side-thrust may be considerable, not only when stopped by a curb-stone, but also when the side-slipping wheels are arrested by a dry, sandy, or rough part of the road.

If the rear wheels of a car weighing one ton skid sideways at a corner, and are brought to rest by the outer wheel running on to a dry, rough, or sloping part of the road, and if two-thirds of the load is borne by the rear wheels, and they attain a sideways velocity of five miles per hour, and stop after sliding three inches beyond the slippery part, then, taking moments about the front wheels, the retarding force is

$$\frac{2}{3} \cdot \frac{W}{2gs} = \frac{2}{3} \cdot \frac{2240 \times 53.8}{64 \times 0.25} = 5020 \text{ lbs. approx. on one wheel.}$$

On a smooth surface, even if dry, the ground would not exert so great a force on the tyre, but when rough and sloping, even greater forces can be exerted.

(To be Continued.)

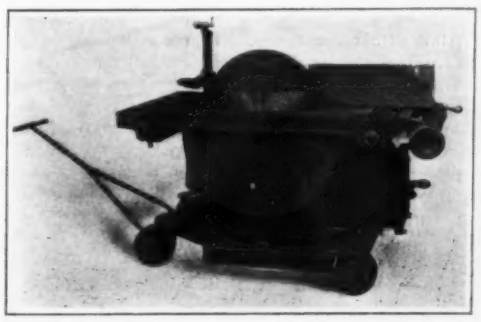
Motor-Driven Circular Saw Bench

OUR illustration, adapted from *The Engineer*, shows a portable motor-driven circular saw bench specially designed for use on battleships, large liners, and so forth. On such vessels there is always a considerable amount of carpentry work to be done, and it is considered that such a tool will also be found useful for yard work and in other cases where it is more convenient to take the machine to the timber than to convey the timber to the mill. The machine is, as a fact, particularly adapted for work in the open by reason of its strong design, and as the motor is inside the main framing and totally inclosed, no trouble is likely to arise either through dust or from the effects of the weather.

The main framing, which is of solid construction, is mounted on a trolley running on wheels for purposes of transport. Provision is also made for bolting the machine to a deck or foundation if desired. The top part of the machine is made to swivel on a turntable, so that it can be swung round and secured at any angle without changing the position of the base. The machine carries saws up to 26 inches in diameter, and will cut through a depth of 8 inches. It is fitted with an adjustable fence, arranged to cant to any angle for bevel cutting, and made to turn over the end of the bench to leave the table clear for cross-cutting. A cross-cut slide with a quadrant adjustable to any angle is also provided for miter cutting.

The saw spindle runs in hardened ball-bearing journals, and has a double ball thrust bearing for taking up end play. The armature of the motor is fitted direct to the saw spindle, and the electrical parts, brushes, etc., are accessible from the top by means of a removable brass cover fitted in the table immediately over the motor. The main standard in which the motor is fitted is made with a large radiating surface to keep the motor cool.

An automatic feed motion is provided. This consists of two horizontal rollers placed one in front and one behind the saw, and connected with each other



Portable Circular Saw Bench.

by a driving chain. The rollers are driven through totally inclosed worm gearing, by a friction disk, and can be instantly stopped or started. The feed can be varied from 5 feet to 45 feet per minute by traversing a friction wheel across the disk, this motion being controlled by a lever at the front of the machine. If preferred, however, the machine can be supplied without the feed gear. The motor is capable of giving out five brake horse-power. Its speed is 1,500 revolutions per minute. The table measures, 4 feet 6 inches by 2 feet 9 inches, and the weight of the machines including the motor, is 25 hundredweight.

Paper Made from Indian Corn

IT is the opinion of M. Ed. Heckel that paper can be successfully produced from corn stalks, and he brought out this subject at a recent meeting of the French Agricultural Society. Among the numerous varieties of corn which are raised in various parts of the world, the great Servian corn is remarkable for the height which it reaches, and in the south of France this is from 10 to 13 feet. The stalks are very thick and they support usually three or four ears of conical shape, the latter being 8 or 10 inches long and they carry large grains of a yellow or slightly reddish hue. From their size, the grains have some resemblance to the horse tooth or Cuzco varieties. The ears are much larger at the base than at the point. Owing to the large size as well as the great strength of the corn stalks of this variety, the author thought that it would be interesting to take up the trials which he formerly made in America as to using corn stalks of the ordinary varieties for the manufacture of paper paste. These trials gave very good results in the quality of the paper which could be made from the corn stalk paste, but what prevented the method from being realized on a commercial scale was that the yield of paper paste was too small. This yield was in fact not over 25 or 30 per cent by weight. In his new researches, the author took advantage of the French paper-making school which is annexed to the University of Grenoble, of which Prof. Barbillon is chief. Some 500 pounds of dry stalks of the Servian maize were sent to the establishment, and as a result, he received a package of 10 pounds of paper made from the corn stalks, with the following report:

The treatment was carried out in order to separate the cellulose of the stalks from the other matter, and this operation must be carried out slowly and carefully so that the cellulose will not be attacked or rendered soluble, as this would bring about a loss. The corn stalks were cut up in short lengths of 3½ inches, and the knots were split up; then the material was put into a treating tank with a soda lye of 12 parts by weight in 500 parts water, using 200 gallons of water for 220 pounds of stalks. The whole was heated under pressure of 5 atmospheres for 6 hours, and then the softened matter was well washed in order to take out all the products which the action of the lye had made soluble. After running through a crusher which broke up the fibers completely, the mass, which was of a brown color, was bleached by a chloride of lime solution. This, however, took some time. The mass was washed with a weak soda lye and with water, and finally it was drained off. A fresh treatment was then made with chloride of lime solution, and this was repeated three times in order to produce a yellowish paste. It was not advisable to continue the bleaching any further as the fibers suffered from rubbing together and became short and fragile. After a last washing to remove all traces of chlorine, the paste was refined, and although this process was made very short, it was very sticky, and this is a considerable disadvantage for paper manufacture owing to the fact that the paste adheres to the presses, gives annoyance and causes losses of the product. The yield in cellulose is 51 per cent by weight, but on a commercial scale not more than 40 per cent should be reckoned. The stalks contain 6 per cent of ash. As to the paper which is produced, it is of stout quality. Its weight is 0.2 pounds per square yard. Prof. Barbillon concludes that the paste made from the Servian corn stalks is fairly good and it can be used in the manufacture of fine papers by mixing with other pastes. In presenting the samples before the society, the author stated that although the present specimens are not as good as what a commercial process would undoubtedly give, it is sufficiently evident that the paper is of a good quality for packing purposes. One point is that it can be very well printed upon, as shown by several samples. Different storekeepers in Marseilles, to whom it was shown, stated that it was satisfactory.

It should be borne in mind also that the paste is of value from the fact that it can be mixed with other kinds of paste for the manufacture of fine paper, and this is an important point. M. Heckel bears upon the idea that the use of corn-stalks for paper manufacture may aid in solving one of the pressing problems, that is the cutting down of forests in order to secure a paper supply. It is well known that the absence of forests has a bad effect upon the rainfall, so that agriculture suffers in consequence. It is fitting, therefore, that agriculture should serve in turn to find some means for preserving the forests, and the present researches lie in this direction.

Cement for Cementing Porcelain and Enamel Plates in Steam Apparatus.—One hundred parts of the finest pulverized clay, 50 parts finest pulverized iron, 20 parts concentrated vinegar, with as much water as will produce a soft paste. The cement must be evenly applied, and left to dry for several days on the hearth wall.—*Drog. Rundschau.*

Science Notes

Bacteria That Feed on Iron.—The organisms commonly denoted as bacteria are a remarkable class, not only as regards the intensity of the actions which they are capable of exercising, despite their small size, but also as regards their extraordinary variety and versatility. Thus, for instance, bacteria played a very important rôle in the decomposition, which led to the production of the coal measures of our earth. A peculiar group of bacteria are the so-called "iron bacteria." These live in highly ferruginous water, and have peculiar power of extracting the iron from the water. Iron is contained in water in the form of ferrous carbonate, and it is this which is consumed by the bacteria, who convert it into iron hydroxide. When these bacteria die they sink to the bottom of the water and accumulate there in a reddish brown layer. It is now considered established that the formation of bog iron is due to this agency. The same bacteria cause trouble at times in municipal water mains, sometimes even causing their complete obstruction.—*Die Welt der Technik.*

Printing Without Printing Ink.—This invention is the product of an English inventor. In the course of some electrical experiments he accidentally pressed a coin, which had fallen on to the table and was rolling off, against a metallic plate covered with a piece of paper, and at the same time against an insulated electric line. To his amazement he saw a sepia print of the coin impressed upon the paper. This happened about twelve years ago. Since then the inventor has followed up this observation, and has now developed a process for printing without printing ink. He uses dry paper impregnated with certain chemicals, whose nature is not disclosed. In the process of printing the paper travels over a metal plate and the type is applied on the opposite side, a current of electricity passing through the paper. According to the particular metal used for the sub-stratum, and according to the mode of impregnation of the paper, a great variety of different colors can be produced, so that multi-color printing becomes an easy matter.—*Die Welt der Technik.*

Skinless Furs.—It is only too well known that furs are subject to the ravages of moths and other unbidden guests. As a matter of fact, it is only the skin to which the fur is attached that attracts these creatures. The idea, therefore, suggests itself to a mind sufficiently bold to make the step, to substitute some other material not adapted as food for vermin, in place of the natural skin. The statement of the problem is simple enough, but its solution is one which most people would hesitate to attempt. Nevertheless, according to an account in *Cosmos*, it appears that the thing has been successfully accomplished. The following is the method adopted: The fur is stretched upon a wooden frame and is then dipped, hair-side down, in a flat dish, the dish being filled with water and placed, with the fur, in a refrigerating room and allowed to freeze. When the fur is frozen to a solid block, the skin is sawed off with a circular saw. It can be further utilized for the manufacture of leather. The surface of the ice block is allowed to melt down a small distance, so as to bring out the ends of the hairs, and then a number of layers of rubber solution are applied. After this has set the ice block is melted off, leaving the hair firmly seated in the rubber. The product so obtained perfectly resembles natural fur in appearance, but differs from it in being quite unassailable by the vermin which attack the latter.

The Word "Gas" and Its History.—It was the Belgian chemist, Joh. Baptist van Helmont (1577 to 1644), who for the first time introduced the word "gas" into use, and experts and philologists have long wondered whence he derived this expression. Max Speter gives a lengthy account of the history of the controversy and the etymology of the word gas. From this it seems that Helmont derived this word by a transformation of the Greek work *chaos*, while others think that the Sanskrit word *akasha* (celestial ether) was the basic word. Ramsay is of the opinion that gas is derived from the German word *geist*. More interesting than the etymology of the word is its history. After the death of Helmont it appears to have been entirely forgotten, and it was not used again until 1778, when Macquer used it in his "Dictionnaire de Chymie." From there Lavoisier took the word over into his system (*traité elémentaire*, 1789). In Germany the word gas was first mentioned again in connection with reports of Montgolfier's balloon ascensions in Paris. It was then called "der gaz," and from that time on the term has been in common use. However, J. Chr. Adelung, a well-known publisher of dictionaries, used it only with reluctance, calling it a barbaric word, which Helmont must have taken from the Hebrew, or perhaps from the Dutch word *geest* (spirit), and he hopes that a more proper word would be found. But the wish of Adelung has never been fulfilled, and Helmont's word has been preserved to the present day.—*Chemiker Zeitung.*

Electrical Notes.

Electric Iron Smelting in Sweden.—A report on experiments in the reduction of iron ore in electric furnaces at Trollhättan has been made by the Association of Swedish Iron Manufacturers, which, with government support, carried on the work. The results showed a reduction of 2.7 tons of pig iron per yearly electrical horse-power, but it is thought this can be increased to three tons. The consumption of carbon electrodes was 22.6 pounds gross, or 11.6 pounds net, per ton of iron, and 816 pounds of coal were consumed per ton. On the basis of selling price of product the experiments were self-supporting. In view of the successful results the government has proposed to raise the price of electrical energy to $13.40 per kilowatt-year; the ironmasters, however, claim that the business will be unprofitable at any rate exceeding $10.72 per kilowatt-year.

In view of the success of the "Maison Electrique" or electric house at Paris, designed by a prominent engineer, G. Knap, the same idea is to be carried out on a larger scale in a large hotel. All the service will be performed by electrical devices, which will almost replace the domestic servants. The dining room is fitted with the ingenious electric table to which everything is sent up from below, the dishes running around the table and stopping before each person, then disappearing again when no longer wanted. A periscope makes the table visible from the kitchen underneath, and orders are given by loud-speaking telephone without leaving the table. Both telephone and periscope are concealed in the chandelier. The new hotel is to contain many special devices of the kind.

Electric Power Transmission from Trollhattan to Stockholm.—Swedish engineers are engaged in a lively discussion of a scheme suggested by Mr. Wikander, for transmitting any surplus electrical energy from the huge Trollhättan falls to Stockholm. The whole of central Sweden is to be covered with a large network of electrical conductors, the Trollhättan lines being linked up with other sources of electrical energy and especially with the large Daläfven waterfalls recently acquired by the city of Stockholm. This scheme would promote the distribution of electrical energy to the small industries, and while satisfying the energy requirements of the Swedish capital for a considerable time to come, would dispose of the project of exporting Trollhättan energy to Denmark. It is even thought that the Trollhättan-Stockholm power transmission scheme may furnish electric heating for the apartment houses of the capital.

A German Eiffel Tower.—At the congress of the German Shipbuilding Society, Director Bredow of the Telefunken Company delivered an interesting lecture on the recent progress in wireless telegraphy, especially in connection with ship installations. A wireless connection between Germany and her colonies, implying spans of up to 3,700 miles, would by no means seem to be impracticable, for even now the huge radio-telegraphic station of Nauen near Berlin, with its tower of 330 feet and only 100 horse-power consumption, has bridged distances of 3,100 miles. Dr. Bredow then made the first public statement of the fact that only a few days ago a marvel of engineering had quietly been completed at Nauen, which could be considered a world wonder of at least the same order as the Eiffel Tower. In spite of violent gales blowing recently, the Telefunken Company had in fact succeeded in the daring task of putting another tower of equal height on top of the freely oscillating iron tower, resting only on a point in a ball joint and kept vertical by three steel cables. The Telefunken tower of Nauen with its present height of 660 feet is, after the Eiffel Tower, the highest building and, incidentally, the most daring structure in the world.

TABLE OF CONTENTS

PAGE

The Psychology of Light.—By R. S. Woodworth.—1 illustration 418

A Lathe for Testing Tools and Drills.—2 illustrations 420

The Tatin-Paulhan "Aero-torpedo." 420

A New Theory of the Cause of Railroad Corrugation.—By E. G. Pellissier.—6 illustrations 421

The Physiological Aspect of Ventilation.—By Theodore Hough 422

Researches in the Value of Potato Varieties 423

The Swiss Railway to the Matterhorn.—4 illustrations 424

Blackpool Promenade Extension Works.—By C. Van Langendonck.—2 illustrations 425

The Discovery of Porcelain in Europe 425

The Trajectory and Mass of Comets.—By Henri Poincare 426

Wheels, Ancient and Modern.—By Henry L. Heathcote.—10 illustrations 427

Motor-driven Circular Saw Bench.—1 illustration 429

Paper Made from Indian Corn 430

Science Notes 430

Electrical Notes 430

The Scientific American Supplement. Index for Vol. 72.

JULY—DECEMBER, 1911.

The * Indicates that the Article is Illustrated with Engravings.

A

Abrasives for different classes of work *269
Adulterations in oils, detecting..155
Aerial propeller, experiments...*154
Aeronaut, protecting the, from lightning *138
Aeronautic engineering in nature*330
Aeronautics, practical application of meteorology to....79, 90
Aeroplane, Doutre's automatic stabilizer *300
Aeroplane, future of, in army...299
Aeroplane military tests in France *348
Aeroplane, power necessary....*298
Aeroplane propeller test plant..413
Aeroplane resistance, analytical representation of *258
Aeroplane in French maneuvers, *241, *244
Aeroplane stability, automatic stabilizers and controls *100
Aeroplane surfaces, parabola in.*342
Aeroplane and wireless telegraphy 176
Aeroplane wires, tension tester.*277
Aeroplanes in naval warfare.... 58
Aeroplanes, some recent types of.*12
Aeroplanes, the stability of....*396
Aeroplanes, wire and wire rope.*361
Agriculture and meteorology 32
Air compressor, gasoline motor driven *88
Air, distribution of germs in the.397
Air elevations, germs at different 48
Airship, sporting, "Parseval V".*172
Airship, what constitutes superiority in an 47, 54
Alloys, field of research.....322
All-steel body model of monoplane *316
Aluminium, bones set with.....160
Aluminium, world's production..399
Ammonia, direct synthesis.....*276
Ammonium, is it a metal?.....274
Anæsthesia in surgery, modern methods 110
Animal machine, respiration calorimeter *89
Animals sleepy and lively in zoological gardens 341
Animals, swill-fed unfit for use.269
Animals, weapons of defense among 2
Ants of Herodotus, the..... 57
Appendicitis, is it a new disease?.214
Arc, physiological effects of the mercury 235
Architecture, the dawn of.....*145
Armies, art of moving.....131, 150
Arsenic, electrolytic copper free from 253
Art, the distorting mirror in..*248
Art, undeveloped, of soaring...*332
Arterial pressure and aviation..315
Artillery, the ideal of the field..*84
Astronomers, team work of the world's *146, *162, *179 *202, *210, *226, *247
Astronomy, photography an aid.. 86
Astronomy, recent developments.278
Austin, Louis Winslow, wireless expert *122
Automatic alternating current system for railroads..... 29
Automobile novelties *60
Aviation and arterial pressure..315
Aviation, a black day in.....*252
Aviation, gyrostatic force of rotary engines for *156
Aviation, insect *392
Aviation, vegetable *330
Aviator, as a scout.....*244
Aviators, life preservers for.....*48
Aviators and return flight of pigeons 391

B

Balloon, hot-air, of twentieth century *204
Balloons, guiding by wireless....*27
Bark, products from willow....*221
Basket making, yellow paper in.*24
Battleship, trials of "Danton"... 35
Bean, Soya, utilization of.....115
Beauty, machine, evolution in engineering structures *180
Bells of Pisa's leaning tower... 24
Betterment of power plant..... 42
Billets, furnace for heating steel.323
Biology and medicine, radium in.111
Biology of the savant.....169
Biplane, Wright's model "B"..*380
Bird flight, mechanical explanation of *349
Blackpool promenade *425
Bladder, gas, of bony fishes.... 69
Blaringhem on his new plants... 83
Blast furnace smelting with oil.263
Blasting off side of mountain...*61
Block-signal system for steam railroads 29
Blueprints, lathe brackets for..*191
Blueprints from printed matter.220
Blueprints, use for old.....323
Boat, Roman, unearthed in England *249
Boat, wireless-controlled *261
Boats, oil driven, in Canada....*45
Bottles, vacuum-jacketed, heat-insulating *53
Brennan's monorail car.....*304
Bridge construction in America, recent 30
Bridges, extensometer methods.. 69
Bucket chain excavator *273
Bunkering steamers, modern methods of *385
Bureau, municipal efficiency....400
Bureau of Standards, National..*257
Butter, softness as a defect in..320
Butterflies, headless 171

C

Cables, loaded telephone.....*205
Caisson sickness and compressed air 270, 282
Calcium chloride, drying furnace blasts with *301
Calcutta and her water supply..*44
Camera, mightier than the eye.*305
Campanile at Venice, new..... *1
Cane, a drinking *91
Canal, hydro-electric energy from 27
Cannon Falls hydro-electric development *401
Car, Brennan's mono-rail.....*334
Car for oiling streets.....*317
Cars, Newark rapid transit....*120
Cargo, magnets for handling... 88
Caries, prevention of dental....363
Catalytic furnace, a proposed...323
Cells, effects of radium on living 56
Cement and the colloidal theory. 83
Cement digging by machinery..*273
Cement, researches in use of....317
Center indicating tool, handy...*64
Cereals, testing for their resistance to disease *221
Chemical fertilizers, European use of 80
Chemical products, poisonous... 62
Chemical research and industrial progress 14
Chemical societies, international association of 136
Chemistry, an excursion in physiological 318
Chemistry of mummification...106
Cheese, cheddar, making.....*408
Chimneys at Rochester *333
Cigar pocket lighter.....*43
Cinematograph, the Gaumont speaking *80
Cinematography and lantern projection *57
Circumference of a circle of given radius *135
Clay, potter's, industry of Cornwall *129
Clock-time related to solar time.*83
Coaches, fire tests on steel passenger *225
Cobweb, the value of a.....*233
Cocaine, manufacturing of.....*171
Cold working and re-heating metals 71
Colloids in cement 83
Comet's tails, theory of.....*70
Commerce, what it owes to chemistry 14
Compass, construction and principles of the gyro.....*200
Concave appearance of the earth from balloons *227
Concrete construction, example of modern *372
Concrete silos and silage.....*232
Condiments and stimulants.....415
Conservation factors, cost of power 314
Conservation of mass *262
Constantine the Great, portrait.*220
Control, method of motor.....*356
Convention of Railroad M. M. A., 1911 41
Conveyer, electrical motor driven for cargo *168
Copper, electrolytic, free from arsenic 253
Copper tempering, lost art of...117
Corpses, identification of charred, by X-rays 323
Corpses, photographing of for identification 349
Cost of power from sun and coal.359
Current rise, automatic device for preventing *356
Curve tracer for temperature..*339
Curves of depreciation in economics *374
Cygni, famous star, No. 61..... 67

D

Dædalian or flying machine, a..*286
"Danton," trials of battleship... 35
Dawn of architecture, the.....*145
Deception, prejudice and sense..367
Dental caries, prevention of....363
Deperdussin monoplane, the....*360
Depreciation, absolute and theoretical *374
Development during exposure...106
Diamond fields, S. Africa, Kimberley mines in.....379
Diamond tools, technical uses..*268
Diamonds, phosphorescence of.. 55
Diesel engine on oil-driven boats..*45
Dirigible, speed measurement in Zeppelin 415
Discovery of porcelain.....425
"Diseases" and flaws of metals.*133
Distance, the sun's..... *7
Dock, new huge, at Southampton*113
Doutre stabilizer, the.....*300
Drain effluents, mechanical aids.*228
Drill, new multi-spindle.....*232
Dynamite, enormous discharge of..*61
Dynamo design 203

E

Earth connections 304
Earth, fertility of black.....160
Earth, the, as a radiator.....284
Earths, genesis of the rare.....327
Earthquakes and luminous phenomena 220
Economics, a question of industrial *374
Efficiency, standards of, in performances 347
Electric lamps, automatic regulator for 319
Electric stage lights 53
Electric traction project, Paris region 73
Electric trains, London's.....*164
Electric traveling cranes and handling materials *357
Electric waves directed by wires.398
Electric waves guided by wires, *4, *20
Electrical precipitation of suspended particles *215
Electrical steering 345
Electrically curing meat 331
Electricity in ice plants.....*340
Electricity meters *28
Electricity, pig iron production.132
Electricity, seasoning wood by..125
Electrolytic copper free from arsenic 253
Electrometer and radio-collector.*155
Electroplating, a simple apparatus *219
Electron theory simply explained.159
Elements, their inter-relation and origin *194
Embryo, action of radium upon.*237
Emulsified oil, removing from water 299
Energy and matter, radiant, *6, *22, *39
Engine, Diesel marine *132
Engine, the motor fire.....*165
Engines, methods of controlling steam *383
Engines, tar as a fuel for Diesel.387
Engineering, technical features of telephone *63
Eros and the sun's distance.....168
Evolution, paleontologist's view.108
Evolution of the umbrella.....*137
Excavator, bucket chain, a.....*273
Excursion into physiological chemistry 318
Exhaustible and inexhaustible supplies 331
Extensometer methods and bridges 69
Eye, effect of mercury arc upon.235
Eye, effect of ultra-violet rays.. 78

F

Factory walls in modern concrete construction *372
Fertilizers, chemical use of European 80
Fibers, length of wood.....*211
Fig trees, giant vegetable growths *189
Finger prints for personal identification *326
Fire engine, the motor *165
Fireless locomotives: superheated water vs. coal fire.....*389
Fire prevention *34
Fish culture as an anti-malarial measure 275
Fish life 87
Fish life, photography in..... 87
Fishermen of the Sea of Galilee.*289
Fishes, gas bladder of bony..... 69
Flies, prizes for catching.....*229
Flour testing of Paris bakers..*337
Flying machine, $15,000 prize, Gould 85, 256, 323
Flying machine, suggestions for.*286
Fossil remains of man.....372
Flywheel, high-speed cast iron.*285
Foundries, lifting magnets in...218
Foundry, labor and time saving.*375
Foundry practice, manganese and silicon in 143
Freight handled mechanically..*168
Freight locomotive, German compound 4-cylinder *88
French inventions, new and interesting *382
Frost protection in orchards...*281
Fruit trees, revenue from roadside 363
Fuel for Diesel engines, tar as a.387
Furnace, a proposed catalytic...323
Furnace blasts, drying with calcium chloride *301
Furnace, service for in modern industrial *184

G

Galilee, fishermen of the Sea of.*289
Gambling system at Monte Carlo.*46
Gas engines, large, of two-cycle type *350
Gas engine started with steam..165
Gas engine waste heat to turbine 32
Gasoline motor-driven air compressor *88
Gasoline motor-testing laboratory *276
Gas power plants, modern in U. S. 32
Gas power plants, operating costs.343
Gas, tool hardening by..... 11
Gases, pressure of light on.....*70
Gastric secretions, method of studying *188
Gearing, new construction in worm *173
Gelatine, norgine, a new vegetable 23
Generator, starting up a 30,000 horse-power *353
Genesis of the rare earths.....327
Geography, new science of..... 66
Geological time, duration of....150
German view of our Panama canal worries 206
Germs at different air elevations 48
Germs, distribution of in the air.397
Geyser, a model *120
Giant twin stacks *333
Glass, varieties of strass..... 38
Goethe, Johann Wolfgang von...*56
Gold, variations in purchasing power 163
Goldschmidt reaction, the *346
Gould $15,000 flying machine prize 85, 256, 323, 416
Grain tester for commercial use.*92
Grand Trunk Transcontinental Canadian Railway *49
Grapevine pest in France, new.. 67
Ground sloth, a new group.....*81
Gun-straightening machine *325
Gyro compass, the..... .*200
Gyrostatic force of rotary engines *156

H

Hair, horse, in relation to commerce *328
Handling materials, up-to-date handling of *357
Havre, seaport improvements at.165
Heat-insulating efficiency of vacuum-jacketed bottles *53
Heat, superheater using waste.*169
Heredity in insanity 271
Herodotus, ants of..... 57
High-frequency meter *91
High-speed cast-iron flywheel...*285
Highways of London during Roman occupation *140
Historiometry as exact science...251
Horizontal gun-straightening machine *325
Horse, appraisement of the.....214
Horse hair, in relation to commerce *328
Horse, wane of the.....229
Household inventions, simple..*157
Hydraulic power for Constantinople 343
Hydro-electric energy from canal 27
Hydro-electric plants in Norway.275
Hydrogen and nitrogen catalytic union of *276
Hyogo-Kobbé, port improvements. 25

I

Iceland spar and sodium nitrate.117
Ice plants, electricity in.....*340
Indexing in degrees, plate for..*128
Impulse marine turbine, German.*344
Incandescent lamps, method of instantaneous performance ...297
Industrial progress and chemical research 14
Insanity, heredity in 271
Insect aviation *392
Insect pest, campaign against flies *229
Insect, the stick 94
Insurance against unemployment in France 394
Interest, system of computing...288
Inventions, interesting new *13
Inventions, interesting new French *382
Inventions, simple household...*157
Inventions, useful little things..*13
Investigator, the career of the...182
Ions, evidence for presence of..*186
Ionium collector and radio-collector *155
Iron, the supply of.....249
Iron tube tunnel, new Paris.... 23
Iron-ore supplies of the world..306

K

Kerosene oil tractor for narrow-gage railway *68

L

Laboratory and commercial production of oxygen *254
Laboratory small, experiments for presence of ions .....*
Laboratory thunder and lightning in *373
Laboratories of Paris bakers for flour testing *337
Laboratories, physical apparatus of European *76
Laborer's worth, measuring the. 82
Lamps, method of performance of incandescent 297
Language and patents, international 204
Lathe for testing tools and drills *420
Lathe brackets for blue-prints..*191
Leaning tower, bells of Pisa's... 24

Life and light, effect on lower organisms *77
Life preserver for aviators *48
Light and life, effect on lower organisms *77
Light, pressure of, on gases *70
Light, physiology of 386, 402, 418
Lights, electric stage 55
Lighters, pocket cigar *43
Lightning made to order *373
Lightning, protecting aeronauts from *138
Limestone in Syria, self burning 117
Lithographic pencils, English 11
Locomotive, German four-cylinder compound freight *88
Locomotive, new 14-wheeled express *284
Locomotive, turbine at Milan 112
Locomotive, what is its time worth? 119
Locomotives, electric for the Lötschberg tunnel *136
Locomotives, fireless *389
Logistics, or the art of moving armies 131, 150
London, new view of Roman *140
London's electric trains *164
Lumber, substitution of 107
Luminosity, distribution of in nature 352

M

Macadam roads, deterioration and cure 190
Machine beauty *180
Machine molding and foundry *375
Machine, the animal *89
Meat curing electrically 331
Magnet, measuring strength of *107
Magnetic work, ocean 3, 26
Magnets for handling cargo 88
Magnets, lifting, in foundries 218
Magnets, manufacture of permanent *312
"Maine" cofferdam, unwatering 112
Malaria, some facts about 390
Map, the great star, star counting *146, *162, *179, *202, *210, *226, *247
Man, fossil remains of 372
Manchuria, the plague in *110
Manganese and silicon in foundry practice 143
Manufacture of permanent magnets *312
Marine Diesel engine *152
Marine turbines, German impulse *344
Mathematical energy wasted 255
Mathematician, futility of amateur efforts 235
Matter indestructible and uncreatable 262
Mechanism, acme of refinement 187
Medicine and biology, radium in 111
Mendelian inheritance of psychic defects 271
Mercadier-Maguinna system of telegraphy *329
Mercury arc, physiological effects 235
Metals, flaws and "diseases" of *133
Metals, some properties of 71
Metals synthetic from non-metallic elements 274
Meteorology and agriculture 32
Meteorology practical application to aeronautics 79, 90
Meteors, number visible at different seasons 280
Meter, a high frequency 291
Meter, a new steam *69
Meters, electricity *28
Metric system and England 59
Midnight visit to zoological garden 311
Military aeroplane tests in France *348
Mill supply in Germany, municipal *33
Mines, history of the Kimberley 379
Mirror, the distorting in art 248
Modern tendencies in bridge construction 30
Molding machine *375
Molecule, wonders of the microcosm of the 159
Money orders, printing *161
Monoplane, the Deperdussin 360
Monoplane, the R.E.P. *316
Mono-rail car, Brennan's mechanical principles of *334
Monte Carlo, gambling at *46
Motor control, new and superior method *356
Motor fire engine, the *165
Motor-driven circular saw bench, ... *429
Motor-testing laboratory, modern gasoline *276
Mountains, formation of by water *124
Moving pictures, application of cold light to *57
Multiplex telephony and telegraphy *4, *20, *36, *52
Mummification, chemistry of 106
Municipal efficiency bureau 400
Municipal milk supply in Germany *33
Municipal wastes and river and harbor waters *17
Mushrooms and oxygen 51
Mutations among shrimps 245

N

National Bureau of Standards, Washington, D. C. *257
Nature, luminosity in 352
Naval warfare, aeroplanes in 58
Netting, machine for making wire *369, 373
New Zealand east coast petroleum fields 315
Niagara Falls, the power of *208
Nitrate supply for national defence 126
Nitrogen question from military standpoint 126
Norgine, a new vegetable gelatine 23
North Africa, Roman ruins in *321

O

Observational science, characteristics of 263
Ocean magnetic work 3, 26
Oil, blast furnace smelting with 263
Oil-driven boats, Canadian lakes and canals *45
Oil tractor, kerosene, for India railway *68
Oil well, great on fire *177
Oils, detecting adulterations in 155
Oiling streets, car for *317
Optics, subjective aspects of, ... 386, 402
Ore supplies of the world, iron 306
Osmotic growths 64
Oxygen, laboratory and commercial production of *254
Oxygen and mushrooms 51

P

Painters, vagaries of great *248
Paleontologist's view of evolution 108
Palms, uses of the royal *280
Panama canal, German view of our worries 206
Paper from Indian corn 430
Parabola in aeroplane surfaces *342
Particles, electrical precipitation of *215
Parseval V." sperting airship *172
Pearl, sick necklace of Madame Thiers 171
Pearls ordinary and extraordinary 166
Pencils, English lithographic 11
Perfume plant, Ylang Ylang 154
Perpetual motion machine, a new radium 239
Petroleum fields of New Zealand 315
Photographic images after fixing 359
Photographic receiver for wireless signals *309
Photographing corpses, for identification 349
Photographs upon watch lids, caps and dials *230
Photography, aid to astronomy 86
Photography, document, use in the courts *305
Photography in fish life 87
Physical apparatus of laboratories, new *76
Physics, the fundamental concepts of 319
Physiological aspect of ventilation 422
Physiological chemistry, an excursion into 318
Physiological effects of low temperatures 423
Pig iron production by electricity 132
Pigeons, return flight of carrier 391
Pine wood, utilization of dead *197
Pivoted rocker in Sanders teacher 232
Plague in Manchuria *110
Planets, the fate of the 238
Planimeter, testing for accuracy *71
Plant food, what is? 399
Plants, Blaringhem on his new 83
Plants, effect of tobacco smoke *196
Plants, ice, electricity in *340
Plants in Norway, hydro-electric 275
Plants, operating costs of gas-power 343
Plants, the senses of 598
Plate for indexing in degrees 128
Pocket cigar lighters *43
Poisonous chemical products 62
Poplar, the yellow, in basket making *24
Port Improvements at Hyogo-Köbbé 25
Portable air compressor *88
Portraits, Roman, first century 76
Post cards, drying picture 339
Postage stamps, abolition of 272
Potter's clay industry of Cornwall *129
Power, cost of; conservation factors 314
Power derivable from ocean waves *365
Power of Niagara Falls *208
Power plant betterment 42
Power plant, rapid depreciation and business 224
Power from sun and from coal, cost of 359
Prehistoric man and the human dwelling *145
Prejudice and sense deception 367
Pressure, aviation and arterial 315
Prevention of fires *34
Principles of original research 10
Printing post office money orders *161
Printing telegraphy, practical aspects of *74, *95, *98, *118, *134, *148, *166, *181
Projectile, combination *84
Propellers, experiments with aerial *154
Profection of water from municipal wastes *17
Psychology of light, the 386
Purification, new apparatus for sewage *228

R

Radiant energy and matter, *6, *22, *39
Radiator, the earth as a 284
Radio-active substances in therapeutics 29
Radio-activity, how measured *116
Radio-activity of snow 91
Radio-activity, recent researches in the field 174
Radiometer motion and very high vacuum 88
Radio-telegraphy, development *338
Radium, action of, on embryo *237
Radium in biology and medicine 111
Radium, effects upon living cells 56
Radium perpetual motion machine 239
Railroad construction, testing materials of *225
Railroad Master Mechanics' Association 41
Railroads, block signal system 29
Rails, new methods of testing *403
Railway, Canadian Grand Trunk Transcontinental *49
Railways, rolling stock of Japanese 107
Rapid transit cars, Newark *120
Rays, ultra-violet and the eye 78
Rays, velocity of Röntgen 185
Reaction, the Goldschmidt *346
Reclamation Service, the United States *97
Recording apparatus for loss in weight *59
Relativity, the principle of 319
R.E.P. monoplane, latest model *316
Repair shop and its locomotives 119
Report on sewage disposal investigations 11
Researches in value of potato varieties 423
Research, principles of original 10
Reservoir of Calcutta water supply *44
River and harbor water and municipal wastes *17
Roads, deterioration and cure of macadam 190
Rolling mill driving; application to geared steam turbine 32
Rolling of ships and capsizing 310
Roman portraits, first century 76
Roman ruins in North Africa *321
Röntgen rays, velocity of 185
Ropeway, wire, for German East Africa *65
Rubber industry, present status *209
Rubber synthetic 115
Ruins in North Africa, Roman *321

S

Saw, and how to use on wood and metal *266
Salinity of sea water 139
Sanders teacher in aviation *32
Savant, the biology of 169
Scale for measuring merit of English writing 158
Sciences, characteristics of the observational 263
Screw threads, stresses on *55
Ships, rolling of and possibility of capsizing 310
Shrimps mutations among 245
Sea water, salinity of 139
Seaport improvements at Havre 165
Secretions, method of studying gastric *188
Seeds, germinated in heated soil 60
Seismology, setback to official 208
Senses, evidence of, misleads us 367
Senses of plants, the 398
Service, mechanical, for the plant furnace *184
Sewage disposal report 11
Sewage disposal, new process of 371
Sewage purification, apparatus for wireless *309
Sewer system of Havana *412
Signals, photographic receiver for wireless 8309
Silage and concrete silos *232
Simplon tunnel, ventilating 53
Skis, their construction and use *411
Sloth, a new group of ground *81
Smelting, blast furnace, with oil 263
Snails in Ceylon 154
Snow, radioactivity of 91
Soaring, the undeveloped art *332
Societies, international association of chemical 136
Soda fountains for trains 119
Sodium nitrate for Iceland spar 117
Soils, plant food and crop yields 399
Soil, seeds germinated in heated 60
Solar physics, spectroheliograph *108
Southampton, new huge dock *113
Soya bean products, utilization 115
Spectograph and spectroscope, new *16
Spectroheliograph in solar physics *108
Speeds, traveling at high, *358, *370
Springs, ancient methods of finding 357
Stacks, giant twin *333
Stage electric lights 53
Stamps, abolition of postage 272
Standards, National Bureau of, and its work *257
Standards of efficiency 347
Star, famous No. 61 Cygni 67
Star, the great map. Star counting *146, *162, *179, *202, *210, *226, *247
Starch, fire-proof 374
Stars fixed, proper motion of 128
Stars in space, their motion 300
Starting up a 30,000-horse-power generator *353
Strass, varieties of glass 38
Steam boiler automatic water regulation *364
Steam, gas engine started with 165
Steam meter, a new *69
Steamers, modern methods of bunkering *385
Steamships, foundation wall for giant *68
Steel, power required to cut 406
Steering, electrical 345
Steering gear of vessels, electrically actuated 545
Stereoscope, scientific use for the, ... *117
Stellar distribution and movements 306
Stick, the insect 94
Streets, car for oiling *317
Stresses in screw threads *55
Submarine, successful night attack 59
Sun and coal, cost of power from 359
Sun's distance determined from Eros 168
Sun's distance, the *7
Superheater using waste heat *169
Supplies, exhaustible and inexhaustible 331
Supply of iron, the 249
Surgery in transplantation of organs and tissues *236
Surgery, modern methods of anesthesia in 110
Swedenborg's suggestions for a flying machine *286
Swill-fed animals unfit for use 269
Swiss railway to the Matterhorn *424
Synthetic metals from non-metallic elements 274
Synthetic rubber 115
System of computing interest 288

T

Tank car for oiling streets *317
Tar as a fuel for Diesel engines 387
Tar, use of on roads 228
Taximeter frauds *260
Tea industry, the Indian 123
Teeth, defective German 43
Telephone and telegraphy, multiplex 398
Telephone cables, loaded *205
Telephone engineering, technical features of *63
Telephone, international lines in Europe 416
Telephone traffic engineering problems *198, *222
Telephony and telegraphy, multiplex *4, *20, *36, *52
Telegraphy, radio, its development *338
Telegraphy, the Mercadier-Maguinna system of *329
Telegraphy, printing, practical aspects of, *74, *95, *98, *118, *134, *148, *166, *181
Telescope, a great modern, on Mount Wilson *393
Temperature curve tracer, a unique *339
Temperature, high recent advances in measurements 302
Tempering copper, lost art of 117
Tension tester for aeroplane wires *277
Therapeutics, radio-active substances in 29
Thermometric and pyrometer scales 502
Tester, a grain *92
Testing a planimeter *71
Testing cereals for resistance to disease *221
Testing laboratory, a modern gasoline motor *276
Testing material of railroad construction 225
Theory of the cause of railroad corrugation *421
Time, duration of geological 130
Time, standard, at Trinidad and Tobago 67
Time, the equation of *83
Traction, electric, project, $30,000,000 73
Traffic engineering, problems in telephone *198, 222
Trains, London's electric 164
Traveling at high speeds *358, 370
Tree, remarkable *189
Tree, uses of the royal palm *280
Tobacco smoke, effect on plants *196
Tools, diamond, technical uses *268
Tool, handy center indicating *64
Tool hardening by gas 11
Tower, rebuilding famous Venetian *1
Trajectory and mass of comets 426
Tunnel, new iron tube double 23
Tunnel, the Lötschberg, locomotives for *136
Tunnel, ventilating the Simplon 53
Turbine, continuous working, 150 days 55
Turbine, cost of development 96
Turbine, gas engine waste heat 32
Turbine locomotive at Milan 112
Turbine, recent efficiencies 48
Turbine steam geared, and rolling mill driving 32
Turbines, German impulse marine *344
Turbine, new internal combustion 59
Turpentine from logs and stumps, ... *197
Two-cycle type of gas engines *250

U

Umbrella, the evolution of the *137
Unemployment, insurance in France against 394
Unloader, continuous at work *193

V

Vacuum, radiometer motion stopped by 88
Vegetable aviation *330
Venice, rebuilding famous tower *1
Voison, R.E.P., Breguet, Nieuport aeroplanes *12

W

Water formation of mountains *124
Water supply of Calcutta *44
Water power in Spain 214
Water power in Wisconsin 80
Water-power plant, development 407
Water, protection of, from municipal wastes *17
Water regulation, steam boiler automatic *364
Water, underground, for public use 125
Watch lids, caps, and dials, photos upon *230
Waves, ocean, power derivable from *365
Weapons of defense among animals 2
Weaving wire into fabric *369, 373
Weight, apparatus for recording loss in *59
Wheels, ancient and modern, and their manufacture 414, *427
Willow bark, useful products from *221
Wing stroke in bird flight *349
Wire and wire rope on aeroplanes *361
Wire ropeway for German East Africa *65
Wireless and mountain obstacle 366
Wood and metal, to use saw *266
Wireless telegraphy and the aeroplane 176
Wireless telegraphy, extension of 163
Wireless controlled boat *261
Wireless signals, guiding balloons *27
Wireless telegraphy in the Kongo 96
Wireless telegraphy, Louis Winslow Austin *122
Wireless telegraphy signals, photographic receiver for *309
Wire netting, machine for making *369, 373
Wires, electric waves directed by 398
Wine, evaporation of 48
Wood and metal, how to use saw on *266
Wood fibers, length of *211
Worm gearing, new construction *173
Wood, seasoning by electricity 125
Wood, utilization of dead pine *197
Wright biplane model "B" *280
Writing, scale for measuring merit of English 158

X

X rays identification of corpses 323

Y

Yellow fever in Brazil, stamping out *225
Ylang ylang perfume plant 154

Z

Zodiacal light 125
Zoological gardens and visit to animals 311

1

67
*83
73
222
164
370
189
280
196
268
*64
11
*1
426
23
136
53
55
96
32
112
48
32
344
59
497
*350
137
394
*193
88
*330
*1
*12
*124
*44
214
80
407
*17
*364
125
*230
*365
2
373
*59
*427
*221
*349
*361
*65
366
*266
176
of 161
*261
*27
ge 96
*122
*309
373
by 308
48
saw
*266
*211
*173
125
*197
*280
178
*325
154
125
311